TRANSACTIONS

OF THE

AMERICAN FISHERIES SOCIETY

1929

FIFTY-NINTH ANNUAL MEETING
MINNEAPOLIS, MINNESOTA
SEPT. 9, 10, 11, 1929

TRANSACTIONS

OF THE

American Fisheries Society

FIFTY-NINTH ANNUAL MEETING

MINNEAPOLIS, MINNESOTA

September 9, 10, 11, 1929

Published Annually by the Society
Hartford, Connecticut
1929

AMERICAN FISHERIES SOCIETY

Organized 1870 Incorporated 1910

*OFFICERS FOR 1929-1930

President .... DAVID L. BELDING, Boston, Mass.
Vice President .... E. LEE LECOMPTE, Baltimore, Md.
Secretary .... CARLOS AVERY, New York, N. Y.
Treasurer .... CARLOS AVERY, New York, N. Y.
Librarian .... JOHN W. TITCOMB, Hartford, Conn.

Vice Presidents of Divisions

Fish Culture .... CHAS. O. HAYFORD, Hackettstown, N. J.
Aquatic Biology and Physics ... WM. J. K. HARKNESS, Toronto, Canada
Commercial Fishing .... PERCY VIOSCA, JR., New Orleans, La.
Angling .... FRED A. WESTERMAN, Lansing, Mich.
Protection and Legislation .... I. T. QUINN, Montgomery, Ala.

Executive Committee

M. C. JAMES, *Chairman* .... Washington, D. C.
C. R. BULLER .... Pleasant Mount, Pa.
C. P. PETERSON .... Bisbee, N. D.
JOHN P. BABCOCK .... Victoria, B. C.
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CHARLES R. POLLOCK .... Seattle, Wash.

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H. S. DAVIS .... Washington, D. C.

*For street addresses see membership list.

Presidents' Terms of Service and Places of Meeting

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1. William Clift ....1870-1872 New York, N. Y.
2. William Clift ....1872-1873 Albany, N. Y.
3. William Clift ....1873-1874 New York, N. Y.
4. Robert B. Roosevelt...1874-1875 New York, N. Y.
5. Robert B. Roosevelt...1875-1876 New York, N. Y.
6. Robert B. Roosevelt...1876-1877* New York, N. Y.
7. Robert B. Roosevelt...1877-1878 New York, N. Y.
8. Robert B. Roosevelt...1878-1879 New York, N. Y.
9. Robert B. Roosevelt...1879-1880 New York, N. Y.
10. Robert B. Roosevelt...1880-1881 New York, N. Y.
11. Robert B. Roosevelt...1881-1882 New York, N. Y.
12. George Shepard Page..1882-1883 New York, N. Y.
13. James Benkard ......1883-1884 New York, N. Y.
14. Theodore Lyman .....1884-1885 Washington, D. C.
15. Marshall McDonald ..1885-1886 Washington, D. C.
16. W. M. Hudson ......1886-1887 Chicago, Ill.
17. William L. May .....1887-1888 Washington, D. C.
18. John Bissell ....1888-1889 Detroit, Mich.
19. Eugene G. Blackford..1889-1890 Philadelphia, Pa.
20. Eugene G. Blackford..1890-1891 Put-in Bay, Ohio.
21. James A. Henshall....1891-1892 Washington, D. C.
22. Herschel Whitaker ...1892-1893 New York, N. Y.
23. Henry C. Ford.......1893-1894 Chicago, Ill.
24. William L. May.....1894-1895 Philadelphia, Pa.
25. L. D. Huntington....1895-1896 New York, N. Y.
26. Herschel Whitaker ...1896-1897 New York, N. Y.
27. William L. May .....1897-1898 Detroit, Mich.
28. George F. Peabody....1898-1899 Omaha, Nebr.
29. John W. Titcomb.....1899-1900 Niagara Falls, N. Y.
30. F. B. Dickerson ......1900-1901 Woods Hole, Mass.
31. E. E. Bryant ....1901-1902 Milwaukee, Wis.
32. George M. Bowers....1902-1903 Put-in Bay, Ohio.
33. Frank N. Clark .....1903-1904 Woods Hole, Mass.

34. Henry T. Root ......1904-1905 Atlantic City, N. J.
35. C. D. Joslyn ....1905-1906 White Sulphur Springs, W. Va.
36. E. A. Birge ....1906-1907 Grand Rapids, Mich.
37. Hugh M. Smith .....1907-1908 Erie, Pa.
38. Tarleton H. Bean ....1908-1909 Washington, D. C.
39. Seymour Bower ......1909-1910 Toledo, Ohio.
40. William E. Meehan...1910-1911 New York, N. Y.
41. S. F. Fullerton.......1911-1912 St. Louis, Mo.
42. Charles H. Townsend.1912-1913 Denver, Colo.
43. Henry B. Ward......1913-1914 Boston, Mass.
44. Daniel B. Fearing....1914-1915 Washington, D. C.
45. Jacob Reighard ......1915-1916 San Francisco, Calif.
46. George W. Field ....1916-1917 New Orleans, La.
47. Henry O'Malley .....1917-1918 St. Paul, Minn.
48. M. L. Alexander .....1918-1919 New York, N. Y.
49. Carlos Avery ....1919-1920 Louisville, Ky.
50. Nathan R. Buller....1920-1921 Ottawa, Canada.
51. William E. Barber ...1921-1922 Allentown, Pa.
52. Glen C. Leach ......1922-1923 Madison, Wis.
53. George C. Embody....1923-1924 St. Louis, Mo.
54. Eben W. Cobb ......1924-1925 Quebec, Canada.
55. Charles O. Hayford..1925-1926 Denver, Colo.
56. John W. Titcomb ....1926-1927 Mobile, Alabama.
57. Emmeline Moore .....1927-1928 Hartford, Conn.
58. C. F. Culler ....1928-1929 Seattle, Wash.
59. David L. Belding ....1929-1930 Minneapolis, Minn.

*A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

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PART I

BUSINESS SESSIONS

TRANSACTIONS

of the

AMERICAN FISHERIES SOCIETY

FIFTY-NINTH ANNUAL MEETING

at

Minneapolis, Minnesota

September 9, 10, and 11, 1929

The Fifty-ninth Annual Meeting of the American Fisheries Society was held at the Nicollet Hotel, Minneapolis, Minnesota, September 9 to 11, 1929. The afternoon session on September 10 was held in the Zoology Building and Natural History Museum of the University of Minnesota.

Registration—Meetings of American Fisheries Society and International Association of Game, Fish and Conservation Commissioners
Minneapolis, Minn., Sept. 9-13, 1929

Registered Attendance

Ashbrook, Frank G., Division of Fur Resources, Bureau of Biological Survey, Washington, D. C.
Adams, C. B., Game and Fish Commissioner, Custer, S. D.
Allen, Wm. Ray, University of Kentucky, Lexington, Ky.
Amsler, Guy, Sec'y Game and Fish Commission, Little Rock, Ark.
Avery, Carlos, President American Game Prot. Ass'n., 233 Broadway, New York, N. Y.
Anderson, S. G., President Minn. State Game Prot. League, Hutchinson, Minn.
Albert, W. E., State Game Warden, Des Moines, Iowa.
Badgerow, Egbert M., Sioux City, Iowa.
Balch, Howard H., 158 W. Austin Ave., Chicago, Ill.
Belding, Dr. David L., Boston School of Medicine, Hingham, Mass.
Benson, John W., Chief Game Warden 1st District, Rolette, N. D.
Berg, Geo., Sup't. Fish Propagation Dept. of Conservation, Indianapolis, Indiana.
Brady, E. C., Kerrville, Texas
Brady, T. P., Dist. Supervisor, Windom, Minn.
Brickner, Joe, Chief of Wardens, St. Paul, Minn.
Brown, Dell, Sup't of Hatcheries, Mammoth Spring, Ark.
Brown, Geo. E., 4508 York Ave., So., Minneapolis, Minn.
Byers, A. F., 1226 University St., Montreal, Canada.
Buckingham, Nash, Ex. Sec'y., American Wild Fowlers, 508 Lenox Bldg., Washington, D. C.
Buntin, Howell, State Game and Fish Warden, Nashville, Tenn.
Bauer, S. P., Fish and Game Department, Lansing, Iowa.
Booker, W. F., Game and Fish Ass'n., Louisville, Ky.
Canfield, H. L., U. S. Bureau of Fisheries, La Crosse, Wis.
Carlson, R. A., State Fish Hatchery, St. Croix Falls, Wis.
Clapp, Alva, State Game Warden, Pratt, Kansas.
Cline, John H., District Supervisor, International Falls, Minn.
Cobb, E. W., Sup't Fish Propagation, Farmington, Conn.
Comee, J. F., Wilmette, Ill.
Comee, L. H., Wilmette, Ill.
Cook, A. B., Jr., Dept. of Conservation, Donia, Mich.
Cook, W. A., U. S. Fisheries Station, Duluth, Minn.
Crary, F. O., Trout Brook Co., Hudson, Wis.
Culler, C. F., U. S. Bureau of Fisheries, La Crosse, Wis.

Chisholm, Wm. F., Shreveport, La.
Dillon, W. R., Assistant U. S. Conservation Officer, Washington, D. C.
Davis, Dr. H. S., U. S. Bureau of Fisheries, Washington, D. C.
Dimond, F. M. 5323 39th Ave., So., Minneapolis, Minn.
Durkee, B. U., State Fish Hatchery, St. Croix Falls, Wis.
Davis, Henry F., E. I. du Pont de Nemours & Co., Memphis, Tenn.
Dayton, George, Game, Forest and Park Commission, Lincoln, Neb.
Ellis, M. M., Univ. of Mo., Columbia, Mo.
Eylar, E. L., Pres. Henepin County Sportsman's Club, 4th Ave. South, Minneapolis, Minn.
Eisenloh, Geo., U. S. Bureau of Fisheries, La Crosse, Wis.
Flanders, E. L., State Fish and Game Commissioner, Montpelier, Vt.
Farley, John L., Executive Officer, Fish and Game Commission, 2212 Havenscourt Blvd., Oakland, Calif.
Forrest, Robt., Ass't. Game and Fish Commissioner, St. Paul, Minn.
French, S. J., Franklin, Indiana.
Fry, Earl A., E. I. du Pont de Nemours & Co., Box 1894, Seattle, Wash.
Goff, B. A., District Supervisor, Aitkin, Minn.
Gale, R. G., Sup't. State Fish Hatchery, French River, Minn.
Gill, G. H., U. S. Fisheries Station, Manchester, Iowa.
Goodman, Frank C., Mason City, Iowa.
Gordon, Seth E., Conservation Director, Izaak Walton League of America, 541 West Randolph St., Chicago, Ill.
Gould, J. F., 126 Arthur Avenue, S. E., Minneapolis, Minn.
Green, Dr. R. G., University of Minnesota, Minneapolis, Minn.
Hildebrandt, F. H., Chairman, Game and Fish Commission, Watertown, S. D.
Henke, Chas. W., Sec'y. Game Protective League, 2511 Lyndale Ave., So., Minneapolis, Minn.
Hunter, J. S., Bureau of Game Refuges, Dept. of Natural Resources, San Francisco, Calif.
Hahn, Martin J., District Supervisor, St. Peter, Minn.
Haldeman, W. W., Minneapolis, Minn.
Haldeman, Mrs. W. W., Minneapolis, Minn.
Hanson, Henry P., Sup't. State Fish Hatchery, Lanesboro, Minn.
Hanson, W. A., District Supervisor, Winton, Minn.
Harkness, Prof. W. J. K., University of Toronto, Toronto, Ont., Canada.
Harkness, Mrs. W. J. K., Toronto, Ont., Canada.
Hesen, Herman O., U. S. Fisheries Station, Louisville, Ky.
Heuchele, G. L., U. S. Fisheries Station, Put-in-Bay, Ohio.
Hewitt, Fred, State Fish Hatchery, Wildrose, Wis.
Hewitt, Fred E., Conservation Department, La Crosse, Wis.
Hirschheimer, L. C., La Crosse, Wis.
Hoofnagle, G. W., U. S. Fisheries Station, Charlevoix, Mich.
Huderle, John, Sup't. State Fish Hatchery, Detroit Lakes, Minn.
Holland, Ray P., Editor, Field and Stream, 578 Madison Avenue, New York, N. Y.
Henderson, Dr. W. C., Ass't. Chief of U. S. Bureau of Biological Survey, Washington, D. C.
Hanlon, Claude, District Supervisor, Conservation Commission, 302 Broadway, New York, N. Y.
Irion, V. K., Commissioner, Department of Conservation, New Orleans, La.
Jensen, Harold, Sup't. State Fish Hatchery, St. Peter, Minn.
Johnson, Arthur, District Supervisor, Grand Marais, Minn.
Johnson, M. S., University of Minnesota, Minneapolis, Minn.
Johnson, O. H., Director of Game and Fish, Pierre, S. D.
Klawon, A. G., District Supervisor, Wheaton, Minn.
Kaupanger, O. L., Sec'y. Minnesota Division Izaak Walton League of America, Station F., R. 1., Minneapolis, Minn.
Klancke, A. C., Supervisor Commercial Fishing, Old Capitol, St. Paul, Minn.
Kilgore, William, Natural History Museum, University of Minnesota, Minneapolis, Minn.
King, Ralph, In Charge Grouse Investigation, Univ. Farm, St. Paul, Minn.
Legge, Llewellyn, Chief of the Division of Fish and Game, Albany, N. Y.
Langlois, T. H., University of Michigan, Ann Arbor, Mich.
Leach, G. C., Chief Division of Fish Culture, U. S. Bureau of Fisheries, Washington, D. C.
Le Compte, E. Lee, State Game Warden, 512 Munsey Bldg., Baltimore, Md.
Llewellyn, B. S., Minneapolis Chapter, I. W. L., 5148 Russell Ave., So., Minneapolis, Minn.
Loos, B. F., 123 So. 11th St., Minneapolis, Minn.
Lowe, John N., Biologist, Dept. of Conservation, Marquette, Mich.
Lund, Carl, Fish Hatcheries Dept., Cheyenne, Wyoming.
Lloyd, Hoyes, Supervisor Wild Life Protection, Ottawa, Canada.
Leffler, Ross L., President State Game Commission, McKeesport, Pa.
La Due, Harry, Editor, American Fur Breeder, St. Peter, Minn.
McCaughan, S. K., 709 Andrus Bldg., Minneapolis, Minn.
McCullough, Geo. W., State Game and Fish Commissioner, Old Capitol, St. Paul, Minn.
McCay, C. M., Annual Husbandry Dept., Cornell University, Ithaca, N. Y.
McCay, Mrs. C. M., Ithaca, N. Y.
McBride, A. G., Game and Fish Commissioner, Lake Andes, S. D.

Madsen, David H., Supervisor Bear River Migratory Bird Refuge, Salt Lake City, Utah.
Mannfeld, G. N., Sup't. Division of Fish and Game, Indianapolis, Ind. (Deceased)
Marks, J. P., Sup't. Fish Hatchery, Paris, Mich.
Masoner, Chas., Dirtrict Supervisor, Bemidji, Minn.
Maurek, Burnie, Game and Fish Commissioner, Bismarck, N. D.
Mecham, J. A., Game and Fish Commissioner, Salt Lake City, Utah.
Meehon, Lloyd, Duluth, Minn.
Metzelaar, Jan, University of Michigan, Ann Arbor, Mich. (Deceased)
Miles, Lee, Chairman, Game and Fish Commission, Little Rock, Ark.
Mix, Oliver W., Sup't. State Fish Hatchery, St. Paul, Minn.
Moore, Dr. Emmeline, Biologist, Department of Conservation, Albany, N. Y.
Munch, Wm. F., District Supervisor, Crookston, Minn.
Murphy, J. P., District Supervisor, Grand Rapids, Minn.
Mauthe, Wm., Chairman, State Conservation Commission, Fond du Lac, Wis.
Neelly, Harry, Game and Fish Commissioner, Searcy, Ark.
Nurnberger, Mrs. P. K., University of Minnesota, Minneapolis, Minn.
Nurnberger, Dorothy, Minneapolis, Minn.
Nyman, Col. M. R., President Minneapolis Chapter, Izaak Walton League of America, N. W. Nat'l. Life Bldg., Minneapolis, Minn.
Osburn, Raymond C., Ohio State University, Columbus, Ohio.
Olson, E. D., Appleton, Minn.
Olson, T. A., State Board of Health, Minneapolis, Minn.
O'Connell, F. B., State Game Warden, Lincoln, Neb.
Patterson, Matt, Director, Dept. of Conservation, Madison, Wis.
Peterson, C. P., State Warden, Bisbee, N. D.
Pinkerton, J. A., Sup't. State Fish Hatchery, Glenwood, Minn.
Pinkerton, Mrs. J. A., Glenwood, Minn.
Purkhardt, Joseph, State Fish Hatchery, St. Croix Falls, Wis.
Pearson, Dr. T. Gilbert, President, National Association of Audubon Societies, 1974 Broadway, New York, N. Y.
Parvin, Roland C., State Game and Fish Commissioner, Denver, Colo.
Quinn, I. T., Commissioner, Department of Game and Fisheries, Montgomery, Ala.
Quinn, Mrs. I. T., Montgomery, Ala.
Roberts, Dr. Thos. S., Museum of Natural History, Univ. of Minnesota, Minneapolis, Minn.
Russell, Mrs. Lucy P., Dept. of Conservation, New Orleans, La.
Rassig, Lillian, Conservation Commission, Old State Capitol, St. Paul, Minn.
Reed, Ray, 158 W. Austin Ave., Chicago, Ill.
Robertson, Andrew, Elks Club, Seattle, Wash.
Robinson, Rex R., Rochester, Minn.
Rodd, J. A., Dept. of Marine and Fisheries, Ottawa, Canada
Rosek, J. M., Dept. of Economics, University of Minn., Minneapolis, Minn.
Reis, Jared M. B., State Game Commission, New Castle, Pa.
Shaver, B. J., U. S. Conservation Officer, St. Paul, Minn.
Shaver, Mrs. B. J., St. Paul, Minn.
Scott, J. T., President, State Game and Fish Commission, Casper, Wyoming.
Sandum, K. O., 832 Andrus Bldg., Minneapolis, Minn.
Slattery, J. P., Hibbing, Minn.
Stattler, H. E., 2223 11th Ave., Duluth, Minn.
Stewart, L. W., State Fish Hatchery, Osceola, Wis.
Stine, P. T., 3728 Oakland Ave., Minneapolis, Minn.
Stoneberg, F. W., North Branch, Minn.
Surber, E. W., U. S. Fisheries Station, Homer, Minn.
Surber, Thaddeus, Sup't. Fish Propagation, St. Paul, Minn.
Suthers, Frank, Conservation Department, Madison, Wis.
Stoddard, Herbert L., U. S. Biological Survey, Washington, D. C.
Steele, Ray C., Sup't. Upper Miss. Wild Life and Fish Refuge, Winona, Minn.
Thompson, David H., Ill. Natural History Survey, Urbana, Ill.
Thompson, W. T., U. S. Fisheries Station, Bozeman, Montana
Tilden, Prof. Josephine E., University of Minn., Minneapolis, Minn.
Torgerson, A. C., Sup't. Fisheries Station, Gretna, Neb.
Totten, J. M., District Chief Warden, Little Falls, Minn.
Totten, Mrs. J. M., Little Falls, Minn.
Tucker, W. A., State Game and Fish Commissioner, Austin, Texas.
Tucker, Mrs. W. A., Austin, Texas.
Thorsten, R. S., State Fish and Game Dept., Lansing, Iowa.
Van Oosten, John, Aquatic Biologist, University of Michigan, Ann Arbor, Mich.
Viosca, Percy, Jr., Director of Fisheries, Dept. of Conservation, New Orleans, La.
Viosca, Mrs. Percy, Jr., New Orleans, La.
Vogele, A. C., Department of Conservation, River Falls, Wis.
Wilke, Bob, Minneapolis, Minn.
Ward, Miss Fern, U. S. Biological Station, Fairport, Iowa.
Warner, Sam V., District Chief Warden, Litchfield, Minn.
Watters, G. O., District Chief Warden, Alexandria, Minn.
Webster, B. O., Division of Fisheries, Dept. of Conservation, Madison, Wis.
Webster, Mrs. B. O., Madison, Wis.

Westerman, Fred A., Division of Fisheries, Dept. of Conservation, Lansing, Mich.
White, E. F. G., 185 Wurtunberg St., Ottawa, Ont., Canada.
Wicks, Judson L., President Minnesota Division of Izaak Walton League of America, 405 Essex Bldg., Minneapolis, Minn.
Wiebe, A. H., U. S. Biological Station, Fairport, Iowa.
Woodward, C. E., State Game and Fish Commissioner, Tallahassee, Fla.
Ward J. Quincy, President Kentucky Division Izaak Walton League of America, Cynthiana, Ky.
Wilcox, A. N., 201 West Rustic Lodge, Minneapolis, Minn.
Winter, J. S., State Division of Fisheries and Game, San Francisco, Calif.
Young, E. C., 36 Melgund Avenue, Ottawa, Ont., Canada.

BUSINESS SESSIONS

The meeting was called to order by President C. F. Culler on Monday morning, September 9, 1929.

Mr. George W. McCullough, Game and Fish Commissioner of Minnesota, introduced the Mayor of Minneapolis, Hon. William F. Kunze, who gave an address of welcome. The address was responded to on behalf of the Society by Doctor Emmeline Moore.

President Culler: The Fifty-ninth Annual Meeting of the American Fisheries Society is herewith convened.

With the reports of the several officers to be given shortly, anything that your President might say at this time would seem superfluous. However, it may be pointed out that the general activities of the Society have been very capably handled by the Secretary, the Treasurer, and the Librarian. Your President has devoted his time to increasing the membership, and it is felt that the report of the Secretary on that subject will be of interest. The index compiled by the Librarian should mean a source of considerable revenue in the future. The permanent fund has been undisturbed, and the report of the Treasurer will show that the finances of the Society are in a flourishing condition.

Great work can be accomplished by this Society, and it is hoped that in the future important results in fisheries conservation will be achieved.

At this time I wish to extend my sincere thanks to those members who have assisted in increasing the membership and caring for the affairs of the Society. I desire also to extend a cordial welcome to the new members of the Society and a hearty greeting to those members whose faces we see at each annual meeting.

ADDRESS OF WELCOME TO UNIVERSITY OF MINNESOTA

BY

DR. THOMAS S. ROBERTS

Director of Natural History Museum, University of Minnesota

Ladies and Gentlemen: In the absence of the President of the University it devolves upon me to bid you welcome to the University and to offer you the facilities of the Zoology building and the museum. The museum, of which I happen to be director, exists as a separate part of the university. It is not a part of the Zoology department, and although we are at present in the Zoology building we hope some day to have quarters of our own. Some of you have been looking through the museum. I hope you will give it critical attention. We have made every possible effort to bring it up to modern standards. The exhibits that you see are all donations. State money has been used to a limited extent in the maintenance of the museum, but practically all the exhibits have been provided by interested individuals, a condition which, I think, you will find to be the case in almost all the museums of the country. We have a small aquarium in the basement, to which I call your attention. Mr. Surber has sent over some lake trout for this meeting. I hope you will make this your home while you are holding your sessions. All of us who are connected with the museum will be glad to do whatever we can to make your stay profitable and pleasant.

REPORT OF THE SECRETARY-TREASURER

To the Officers and Members of the American Fisheries Society:

The membership of the Society has had a net gain during the past year, due chiefly to the activity and effective efforts of President Culler. One hundred and twenty-nine new members have been added during the year. Fifty-six of these have been secured by Mr. Culler. Forty-three members have been dropped for non-payment of dues, while two previously dropped have been restored by payment of arrears, leaving a net gain of eighty-eight. I think that is about the largest gain we have had in one year in recent times. No requests have been received during the year for transfer of members from the active to the life membership list. Only one life member has been added by payment of the $50 fee, so that it has been rather a lean year in the addition of life members.

Some of the other members who have been helpful and active during the year in securing new members have been: Dr. Emmeline Moore, who has recommended nine members; John W. Titcomb, eight; F. A. Westerman, six; L. H. Spragle, Chairman of the Executive Committee, six; C. H. Wilson, three, and W. A. Clemens, three. The secretary has secured thirteen.

It is gratifying to the officers that the index catalogue, which we have been talking about for many years, has finally been completed and printed. It is now available to members. This has been accomplished without the necessity of borrowing from the permanent fund. Prior to this year $180 had been subscribed for this purpose, and orders amounting to $315 were received during this year, a total subscription for this purpose of $495 to date. The cost of indexing and printing the volume was $1,110.22, the difference being borrowed from the general fund. Seven hundred and fifty copies were bound in cloth and two hundred and fifty in paper covers, 1,000 copies in all being printed. The cloth bound volumes are sold at $5 per copy and the paper bound volumes at $4. The receipts from the sale of the index catalogue will, when all are sold, net the Society a profit of about $3,600. It may seem to some members that the index is sold at too high a price, but in order to get it printed it was necessary to charge a substantial sum since we did not have enough money in our general fund to cover the cost. After all, although small, it is a valuable volume, which will be a source of reference for many years to come. It is my suggestion that each volume be indexed hereafter as it is issued, and that the index be bound in the volume, so that the Transactions will always be completely indexed. I have a copy of the index with me for the inspection of any members who have not seen it, and I have order blanks which may be filled out by any who wish to obtain a copy.

The present Secretary-treasurer consented to assume the duties of both offices on condition that the Publications Committee take charge of the preparation of the Transactions for the printing, and do all the editing and proof reading. It was expected that the printed volume could be delivered more promptly than heretofore, but this expectation was not realized. It appears that the time required for submitting proofs to authors for corrections is bound to occasion considerable delay. Additional delay in the issuing of this current volume was caused by the printer. The printing was done at the Connecticut State Reformatory at a much lower cost than at a commercial printing plant, the saving to the Society approximating from four to five hundred dollars a year, an important item in view of our limited resources. The Society is under obligation to the Publication Committee, consisting of Dr. Belding, Dr. Embody, Dr. Davis and Mr. Titcomb for the care exercised by them in editing the volume.

The finances of the Society are in a wholesome condition, notwithstanding the unusual drain occasioned by the issue of the index catalogue. The year has been closed with a balance in the general fund of $633.51 and no liabilities except such allowance as may be made for clerical expenses for the past year, which was not provided for at the last meeting, and some small items for printing separates, for which bills had not been received at the time of making the report.

The permanent fund has grown to $4,000.91. Unless the Society sees fit to make some other disposition of it, it is recommended that $1,000 be transferred from the savings account, which yields only three per cent, to some sound five and a half or six per cent security such as our other permanent funds are invested in.

I have here copies of the financial statement in detail which will save the time of reading it.

AMERICAN FISHERIES SOCIETY

Treasurer's Report

General Fund

Receipts

Balance on hand at meeting of 1928		$ 752.37
Annual Dues		
Individuals and Libraries		
For the year 1924	$ 3.00	
1925	3.00	
1926	9.00	
1927	48.25	
1928	1,286.87	
1929	68.00	

Clubs and Dealers			
For the year 1928		139.92	
1929		10.00	
State Memberships			
For the year 1927		20.00	
1928		150.00	
1929		30.00	
Life Memberships		50.00	
Sale of Publications		167.51	
Catalog Fund		315.00	
International Association of Fish & Game Commissioners, pro rata share for 500 copies multigraphed railroad rate circular		9.54	2,310.09
			$3,062.46

Disbursements

	Voucher No.		
1928 Meeting, Seattle, Washington			
Reporting Proceedings of	3	350.00	
Programs—Pro rata share	8	30.00	380.00
Transactions—1928—Vol. 58			
Printing of 800 copies	23	650.00	
Mailing Jackets for	17	9.50	
Postage for mailing of	19	43.32	702.82
Index—Catalogue			
Indexing Vols. 1 to 57, Inc.	5	450.00	
Indexing Vol. 58	15	15.00	
Printing 1,000 copies of, including postage and mailing	24	642.10	
Express	4	2.37	
Express	14	.75	1,110.22
Postage, Express, Telegrams			
Secretary-Treasurer's office	11	12.00	
" " "	18	31.60	
" " "	25	51.54	
Librarian's Office	7	10.00	
" "	12	5.00	
" "	13	10.00	
President's "	9	5.00	125.14
Printing, Stationery, Circulars, etc.	2	8.75	
" " " "	6	11.25	
" " " "	10	8.40	
" " " "	16	25.39	
" " " "	21	19.08	
" " " "	22	9.75	
" " " "	26	10.00	92.62
Premium on Treasurer's Bond	1	2.50	
Clerical Assistance, Secretary's Office	20	6.00	
Exchange on Checks (Vouchers Attached to Bank Statements)		9.65	$2,428.95

Receipts—General Fund	$3,062.46	
Disbursements—General Fund	2,428.95	
Balance on hand September 1, 1929		633.51

PERMANENT FUND

Cash Balance on hand, 1928 meeting	813.73	
Interest on Savings Account Received	22.18	
Interest on Mortgage Certificate to 6/1/29	165.00	
Total in Savings Account		1,000.91
Certificate of Title Guarantee and Trust Company		3,000.00
Total		4,000.91

The report was referred to the Auditing Committee and later accepted by the Society after the approval of that committee.

REPORT OF THE LIBRARIAN

Since the office of Librarian was created the principal functions have consisted in caring for all surplus copies of the Transactions and to dispose of them by sale whenever called for. Also to endeavor to preserve complete sets, so far as possible to do so. In order to guard against any distribution of the sets which are thus preserved, they have been securely packed and the covers fastened upon the boxes. The sets thus preserved consist of the following:

1876—2 copies	1908—2 copies
1884—1 "	1909—2 "
1885—2 "	1910—2 "
1886—1 "	1911—2 "
1888—1 "	1912—2 "
1889—1 "	1913—2 "
1890—1 "	1914—2 "
1891—1 "	1915—2 "
1892—1 "	1916—2 "
1893—2 "	1917—2 "
1894—1 "	1918—2 "
1895—2 "	1919—2 "
1896—2 "	1920—2 "
1897—2 "	1921—2 "
1898—2 "	1922—2 "
1899—2 "	1923—2 "
1900—2 "	1924—2 "
1901—2 "	1925—2 "
1904—2 "	1926—2 "
1906—2 "	1927—2 "
1907—2 "	1928—2 "

It will be noted that the first publication is dated 1876 while the first meeting was held in 1870. The Society has no copy of the publications for the years:

1877	1883
1878	1887
1879	1902
1880	1903
1881	1905
1882	

Book dealer's prices are offered for the above missing issues.

In addition to the office copies the following Transactions are on hand and for sale:

Vol. No.	*Year*	*No. of Copies*
5	1876	4
25	1895	14
26	1896	23
27	1897	44
28	1898	45
29	1899	0
30	1900	0
31	1901	4
32	1902	0
33	1903	0
34	1904	34
35	1905	0
36	1906	127
37	1907	118
38	1908	139
39	1909	100
40	1910	97
41	1911	89
42	1912	157
43	1913	175
44	1914	23
45	1915	23
46	1916	34
47	1917	69
48	1918	46
49	1919	149
50	1920	148
51	1921	93
52	1922	96
53	1923	80
54	1924	229
55	1925	295
56	1926	200
57	1927	210
58	1928	148

Prices for the above volumes are as follows: 1876 to 1905, inclusive, $3.50 per vol.; 1906 to 1922, inclusive, $2 per vol.; subsequent issues, $3 per vol.

There is an increasing demand from libraries, and occasionally from individuals, for complete sets of the Transactions—including the earlier numbers which are lacking. There may eventually be sufficient demand for the 1905 publication to warrant a reprint. A record is being kept of all requests for copies which are not available. Every member should realize that these publications are worth, as books of reference, much more than the price of the annual dues.

The recently published index is partly responsible for the increased demand for these publications. The price of the index is $5 for cloth binding, $4 for paper binding. It is believed, also, that the quality of the matter published—including some of the scientific papers—is responsible for much of the increasing demand for the later issues. Sales of Transactions for the past year amounted to $167.51, as shown by the Treasurer's report.

REPORTS OF VICE-PRESIDENTS OF DIVISIONS

REPORT OF DIVISION OF FISH CULTURE

By James A. Laird

The Seattle meeting was educational and interesting, the city and surrounding country most beautiful. Mr. Pollock and his colleagues are to be congratulated for the splendid papers, the royal entertainment and the large attendance, so many foreign countries being represented.

The salmon industry is an immense problem in its many phases, and its protection and perpetuation is ably and fearlessly handled by Commissioner O'Malley.

The Fraser River situation is pitiful and we all hope with Mr. Babcock that the Canadian and U. S. Governments find the necessary means of replenishing the criminally depleted waters. Fish ladders and irrigation ditch screens are still another problem necessitating some heavy thinking.

The migrating of striped bass on Pacific Coast and increasing abundance of same, is most gratifying.

The Western and Japanese oysters are very nice but those from Chesapeake Bay, Long Island or Cape Cod can not be surpassed anywhere in the world.

The paper by Dr. Belding is proven more forcibly each succeeding year, especially in streams similar to that of the South Side Sportsmen's Club of Long Island, and by whom I am employed as Fisheries Superintendent, and to counteract the increased temperature, we are putting in several thousand dollars worth of trees and shrubbery and plan the planting of several thousands of willows and soft maples; our shallows we will deepen by diverting the current and narrowing the stream where necessary and the building of dams where possible without spreading the water over a large area.

The South Side Club, while a private institution, has done much for conservation, owning nearly 4,000 acres on which are five ponds and four miles of brook, all of which is patrolled and protected by game wardens paid by said club. Two ponds of a total of over 200 acres are duck sanctuaries near which no one is allowed to go from October 1st until after February.

The whole area is a sanctuary and benefits the surrounding country.

Some of the activities of the above club are the rearing of land-locked salmon for public waters, the introduction of smelt into land-locked water, the successful introduction of Montana Grayling into Eastern water from eggs, and the sending of several hundred thousand eyed brook trout eggs each year to the West for planting in Glacier National Park and elsewhere as Superintendent Thompson of Bozeman will attest.

The planting of trees along water courses should be brought to your attention. Willows especially are quick growing and easily and inexpensively procured. A willow twig if cut diagonally with a sharp knife, shoved a few inches into the ground and tightly tamped in the early Spring, will grow without any attention. A small piece of wire cloth would prevent mice or rabbits eating off the bark.

There has been an electrical apparatus invented by Mr. Henry Eickhoff of Elberon, N. J., which will kill insects when attracted by a light. This should be of interest to fish culturists as a means of collecting fish food, for we have all seen the thousands of bugs of all kinds flying around street and other lights. The insects could be collected below the apparatus and fed during the day.

I caught an American Bittern or Quark, a species of night feeding bird, in a steel trap on a pole set for kingfishers, over a fingerling trout pond. This bird was placed in a wire cage and not being much hurt did not lose its appetite. It was fed all the trout it could eat for three days, to get an idea of its bunker capacity and to note the size fish it would take. A twelve-inch trout was taken with some difficulty, six six-inch trout were swallowed each night for three nights and a great many three-inch fingerlings. We estimated it could use two pounds of fish every twenty-four hours, so you may compute how large a fish hatchery would be necessary to supply a hundred birds one year. At the rate of 75c a pound for trout and for the sake of comparison, we will say any other game fish is of equal value; one night feeding bird eats five hundred and forty-seven dollars and fifty cents worth of fish each year it lives. How many fishermen catch that value of fish per year?

REPORT OF THE DIVISION OF AQUATIC BIOLOGY AND PHYSICS

By Dr. H. S. Davis

In presenting a report to the Society from the Division of Aquatic Biology and Physics, I wish to point out the importance to the pond-fish culturist of a thorough understanding of the physical, chemical and biological agencies operating in shallow lakes and of the practical application of this knowledge to pond culture. As you are all aware, pond culture is fundamentally quite different in many respects from other forms of fish culture. In the propagation of trout and salmon, for instance, we are chiefly concerned in providing a good flow of well-aerated water at the proper temperature and a sufficient amount of suitable food at frequent intervals. In pond culture, on the contrary, we require only relatively small amounts of water and our food problem becomes primarily a production problem. In short, trout culture may be likened to the feeding of cattle and pigs in pens or corrals while pond culture is analogous to rearing stock in a pasture or on the open range.

Each phase of fish culture has its peculiar problems but I am sure you will all agree that the problems confronting us in pond culture are, on the whole, more complex and baffling than those facing the trout culturist. In pond culture we must deal with a complex series of interacting physical, chemical and biological factors whose relations to each other are often far from clear and are not easily subjected to investigation. We construct a pond, fill it with water, stock it with fish and hope for the best. Sometimes the results are satisfactory but more often, I fear, only the most confirmed optimist could characterize them by such a term.

It is not my intention at this time to discuss the problems and difficulties which are inherent in pond culture. I simply wish to emphasize the great importance of these problems and the necessity for intensive research in the various phases of pond culture. If we are to provide the fish in our ponds with a favorable environment we must know what is going on in these ponds. All organisms are dependent on a complex of factors for their existence and development and if we are to get the best results we must know how to maintain the proper balance of these factors to insure optimum conditions for the propagation and growth not only of the fish themselves but of the myriads of organisms which enter directly or indirectly into their food supply.

The similarity between the problems of agriculture and those of its sister science, aquiculture, has been frequently emphasized but I feel that this has sometimes been overdone. It is very true that in both sciences we are confronted with the same fundamental problems but the working out of these problems on land and in water may lead us in quite different directions. In both soil and water, for instance, we find nitrifying, denitrifying and nitrogen-fixing bacteria but in ponds the denitrifying and nitrogen-fixing bacteria appear to be relatively unimportant and aquatic plants are dependent almost entirely on nitrogen which is already in circulation. Furthermore, it appears that there is little evidence that in fresh water the circulation of nitrogen is unfavorably affected by high temperatures.

If we compare the food of our domestic animals and fish we find that the former are dependent directly on forage crops while in our ponds there is, as was pointed out last year by my distinguished predecessor, a long complicated food-chain starting with the algae and culminating with our game fishes. It is such instances as these that frequently make the problems of the fish culturist even more complicated than those of the farmer.

But what are we doing to solve these problems? In all honesty we must admit that, considering their importance, we are doing very little. The waters suited to our warm-water game fishes have many times the extent of those adapted to trout and yet we have in the past devoted far less attention to pond culture than to the propagation of trout. In Europe pond culture is receiving the attention it deserves but unfortunately the results of their investigations are frequently not directly applicable to our own problems. For the most part the European investigators are primarily interested in carp culture, a phase of aquiculture with which, for the present at least, we are not so directly concerned. Our pond culture for many years to come will undoubtedly be devoted primarily to the propagation and rearing of game fishes and while fundamentally our problems are similar to those of European fish culturists, their solution must frequently take a quite different course. Consequently we must work out our own salvation and not wait for others to solve problems which are peculiarly our own.

REPORT OF THE DIVISION OF PROTECTION AND LEGISLATION

By E. Lee LeCompte

Mr. President and Fellow Members of the Society:

I hereby submit a report on the subject of protection and legislation. The matters contained herein, in my opinion, are worthy of consideration by this honorable body.

The migratory fishes of the Atlantic and Pacific coasts are greatly in need of more adequate protection, which can only be brought about by legislation. The question arises in my mind and I feel adequate legislation for the further protection of migratory fishes can only come through Federal legislation. It seems to be impossible for the conservationists of this country to secure adequate legislation from the numerous General Assemblies of the Atlantic and Pacific coast states for the further protection of migratory fishes unless the coastal states enacted legislation in concurrence with each other. The legislation of the states in which migratory fishes are found would not meet the situation.

I call your attention to one of our greatest migratory fishes, namely: the shad, which is one of the most palatable and popular fishes and in the days of George Washington and John Marshall, planked shad was regarded as one of the most delicious dishes for the table and is so considered up to the present time. Shad was formerly found on the Atlantic Coast of North America from Florida to New Foundland. Its center of abundance at present seems to be from North Carolina to Long Island.

Every Atlantic Coast State fully realizes that the shad in the past few years has decreased at an enormous rate and unless we are able to secure more adequate legislation which, I repeat, must come through a Federal statute, we cannot hope to stem this depletion.

Only a few years ago the shad production of the Atlantic Seaboard was approximately 26,000,000 pounds. This production has decreased almost 80%, causing the price to advance nearly 500%.

The most striking figures showing the decline of the shad were found in reports of the United States Bureau of Fisheries. In their statistics for the Potomac River, which waters divide the States of Maryland and Virginia, in 1901, 2,979,233 pounds of shad, valued at $119,366, were taken from those waters. Since that date the decrease in the catch has been gradual but continuous. In 1926, the report shows the Potomac River produced 1,034,206 pounds, valued at $217,461. In 1901, shad sold as low in the eastern markets as 4c per pound. In 1928, the average price was from 15 to 40c per pound.

In 1896, the Potomac River produced 2,565,237 pounds of shad, valued at $63,608, while in 1926 less than one-half of the number of pounds were taken, the total revenues showing an increase of 360%.

The shad of the Atlantic Coast, seeking suitable waters for spawning, must run the gauntlet of thousands upon thousands of nets. Due to the fact that the central Atlantic States were inhabited much later than the Atlantic Coast

States, they have been blessed with an abundance of natural resources, the commercial fishermen of the Atlantic Coast having been permitted to take and destroy the fish in a wholesale way, have naturally depleted numerous species of fishes which in former years were abundant.

Transportation of shad was made from the Atlantic Coast to the Pacific Coast beginning 1871, followed by other shipments in 1873 and 1880. From these plantings, shad have multiplied and are found from Southern California to Northeastern Alaska. It was reported in 1925 that California shipped in refrigerator cars to the Atlantic Coast approximately two million pounds of shad which were sold in the eastern markets, as having been caught from the waters of the Atlantic Coast.

There has been within the past few years some agitation for Federal legislation regulating the taking of migratory fishes and a meeting was held in Washington during the administration of the Honorable Herbert Hoover, Secretary of Commerce, to consider ways and means of saving the migratory fishes of this country. However, the same old question arose, namely: requesting co-ordination of the Atlantic and Pacific Coast States.

With these facts before you, I recommend that there should be a Federal statute for the further protection of migratory fishes which would require every person catching them during the spawning season to be compelled to strip all ripe fish of their roe and where there was a hatching station within a suitable distance, to deliver the roe to said station. Where hatching stations are not available, then the person catching ripe fishes, should be compelled to strip them and deposit the eggs in as suitable waters as possible in the neighborhood of where the fishes were taken. Said statute should also provide regulations of size of mesh used in nets, distance permitted to be set from shore (not permitting any net to have a hedging prohibiting the passage of fishes up and down near the shore line), and distance nets should be set apart; also providing for a closed season during part of the spawning period, giving a larger percentage of migratory fishes an opportunity to reach their spawning ground, thereby assuring a larger number of brood fish to deposit their eggs, which would be beneficial to the propagation of same.

I also wish to call your attention to the much-needed legislation for the further protection of black bass in the United States. I do not find any laws prohibiting the purchase and sale of black bass in the following states:

Alabama
Georgia
New Jersey (except under a certain size)
North Carolina } Laws very inadequate,
South Carolina } but quoted.
Tennessee

The other states of the Union and the District of Columbia have laws (however, not adequate), for the protection of black bass and prohibiting the traffic in same. I herein present a list of the States, alphabetically, quoting synopsis from the laws of these States, relative to this important matter.

ARIZONA: Prohibits the purchase, sale, barter or transportation from the State of any fish protected by the Act.

ARKANSAS: Game fish caught in the State, or shipped in from outside, cannot be sold, offered or possessed for sale, but trout caught in other States and shipped in can be sold. Game fish raised in private hatcheries may be sold under permit.

CALIFORNIA: Unlawful to buy, sell, offer or expose for sale any black bass. Shipment of striped bass out of State prohibited.

COLORADO: Prohibits transportation and sale of any fish taken from public or private park, enclosure, lake, or body of water unless same is licensed as provided in Act. Applies to fish held by private ownership as well as to fish acquired under the Act.

CONNECTICUT: Prohibits the purchase, sale, exchange, or exposure for sale or exchange, of any bass except for restocking purposes.

DELAWARE: Unlawful to possess any game fish during the closed season, whether taken within or without the State, and unlawful at any time to barter, sell, offer for sale, or buy, any game fish protected by law.

DISTRICT OF COLUMBIA: Unlawful to offer for sale or sell black bass.

FLORIDA: Black bass may be transported as personal baggage only. Sale unlawful except those caught from Lake Okeechobee and the St. John's River from its mouth as far south as Volusia Bar, including Doctor's Lake and Lake George as part of St. John's River, and the Suwanee as far north as the forks of the river forming the east and west passes, and Crescent Lake, and Lakes Kissimmee, Jackson, Marion, Lizzie, and Alligator in Osceola County.

IDAHO: Unlawful to sell, offer or expose for sale, or possess for sale without a permit, any fish taken in the waters of the State.

ILLINOIS: Unlawful to buy, sell, or barter, or offer to buy, sell, or barter, or to ship or offer for shipment, or receive for shipment, or for any commercial institution, commission house, restaurant, or cafe keeper, or fish dealer, to have any black bass in possession, whether taken within or without the State.

INDIANA: Unlawful to sell, barter, or exchange, purchase or offer to purchase any native fish protected by a size or bag limit law. "Sale" shall include the serving of same as part of a meal by any restaurant, hotel, boarding house or eating house, but may be prepared and served to guest, patron or boarder and his family if lawfully taken by such guest.

IOWA: Unlawful for any commercial institution, commission house, restaurant, or cafe keeper, or fish dealer, to have in possession, buy, sell or barter, or offer to buy, sell, or barter, any black bass whether caught or taken within or without the State.

KANSAS: Unlawful to sell or offer for sale, buy or offer to buy, any bass taken from Kansas waters, except person owning artificial pond or ponds, or engaged in fish culture, may be permitted to sell fish taken from such pond.

KENTUCKY: Unlawful to sell or offer for sale any large or small mouth bass.

LOUISIANA: No game fish may be sold at any time, whether caught within or without the State.

MAINE: Sale of black bass prohibited, except that bass taken by hook and line in Round Pond and in Pennamaquam Lake in Charlotte in Washington County, may be sold and transported within and without the State under rules and regulations of the Commissioner of Inland Fisheries and Game.

MARYLAND: Sale of blass bass prohibited April 1st to July 31st, inclusive. Unlawful to have in possession during said months whether said fish be caught in the waters of Maryland or in any other State. Unlawful to transport from the State or transport into the State any black bass during said months, except fish propagated in private ponds may be sold under a permit from the State Game Warden, for propagation and except anglers are permitted to take black bass in non-tidal water during the month of July, not for sale.

MASSACHUSETTS: Sale of fresh water fish taken in State is prohibited.

MICHIGAN: Unlawful to purchase or sell, or attempt to purchase or sell any bass.

MINNESOTA: Purchase and sale of black bass at any time prohibited.

MISSISSIPPI: Unlawful to sell or buy any game fish.

MISSOURI: Unlawful to offer for sale, sell, or ship for market purposes any game fish caught or taken from the waters of the State, but artificially propagated fish held in captivity may be sold.

MONTANA: Unlawful to sell or offer for sale any of the game fish of the State except fish caught in private ponds by owners thereof may be sold.

NEBRASKA: Unlawful for any commercial institution, commission house, restaurant or cafe keeper, or fish dealer, to sell, or offer or expose for sale, any black bass, whether taken in the State or shipped in from wtihout the State.

NEVADA: Unlawful, except as otherwise provided by law, to buy, sell, offer or expose for sale, any black bass at any time.

NEW HAMPSHIRE: Unlawful to buy, sell, offer or expose for sale, any fish except as permitted by law. Permissive sections apply to owners of private waters and sale of propagated fish.

NEW MEXICO: Unlawful to buy, sell, offer or expose for sale, any game food fish taken from public waters or streams of State.

NEW YORK: Purchase, sale, or exposure for sale of any black bass prohibited, except for propagation.

NORTH CAROLINA: Unlawful to sell black bass less than 25 inches in length, except those caught in Currituck Sound. Unlawful to sell or ship out of the State any species of game fish during closed season.

NORTH DAKOTA: Unlawful to sell, expose for sale, or possess with intent to sell, any black bass caught within the State.

OHIO: Unlawful to buy, sell, offer for sale, barter, give away, or possess for any such purpose any black bass caught inside or outside of State.

OKLAHOMA: Unlawful to sell, offer or possess for sale, any black bass except such as may be taken from privately owned ponds or lakes.

OREGON: Unlawful to buy or sell, or offer or possess for sale, or transport for sale, any game fish except as may be permitted.

PENNSYLVANIA: Unlawful to purchase, sell, or expose for sale, any black bass caught in waters wholly within the State.

RHODE ISLAND: Sale of black bass, trout, pickerel, and yellow perch caught in State prohibited.

SOUTH CAROLINA: Unlawful to sell game fish during months of April, May and June or ship same out of State for sale.

SOUTH DAKOTA: Unlawful to sell or offer for sale bass.

TEXAS: Unlawful to buy or sell, offer to buy or sell, possess for sale, or ship or transport for sale any bass.

UTAH: Unlawful to sell, offer or expose for sale, or to serve in any restaurant, hotel, or other public eating house, or to possess with intent to sell, any bass taken from public waters of State.

VERMONT: Unlawful to buy or sell black bass.

VIRGINIA: Unlawful to buy, sell, barter, or offer to buy, sell, or barter any black bass, but lawful to sell, under permit from Commission of Game and Inland Fisheries, bass caught in waters of Back Bay and its tributaries.

WASHINGTON: Unlawful to buy, or to sell, offer or expose for sale, any game fish taken in the State, or unlawfully taken outside of the State, or unlawfully shipped into the State.

WEST VIRGINIA: Unlawful to purchase or sell, or offer to purchase or sell, or expose for sale, any black bass caught within the State.

WISCONSIN: Unlawful to purchase, sell, barter, or offer to purchase, sell, or barter, or possess for sale or barter, any black bass except those raised in private fish hatcheries.

WYOMING: Unlawful to sell, directly or indirectly, offer for sale, any game fish of the State except those raised in private fish hatcheries.

The interstate transportation of game and fresh water fishes caught in violation of any State law is prohibited by a Federal law known as the Hawes Act. This is a great step forward and the sportsmen of this country owe a debt of gratitude to the Honorable Harry B. Hawes of Missouri who, without a doubt, is one of the most outstanding conservationists of the United States.

Senator Hawes has a bill pending before Congress at present strengthening the Federal law bearing his name and all conservationists should rally to the support of the Senator in securing the enactment of such measures.

It is very encouraging to learn from the above tabulation that forty-two States of the Union and the District of Columbia have enacted legislation for the protection of black bass. However, in the majority of these States, this legislation is inadequate and I recommend that there be some concerted effort on the part of this Association to co-operate with the States in trying to secure uniform legislation in each and every State to prohibit the taking of black bass at any season of the year except by rod, hook and line and prohibiting the sale or purchase or transportation without the State or within, at any time, and if we cannot secure more adequate legislation through State enactment, then I recommend that we try and secure Federal legislation on this important subject.

Discussion

MR. LECOMPTE: Senator Hawes, of Missouri, has a bill pending before Congress looking to the further protection of black bass. As you are no doubt aware, the only Federal statute for the protection of black bass is the Hawes law, which at present prohibits the shipment of black bass out of those States which prohibit such shipments. The Federal statute should provide for the prohibition of shipment of black bass out of any State in the Union. State or Federal legislation should prohibit the sale within or without the State of any black bass, provide an open and closed season and designate the manner in which black bass may be taken.

At the last session of the General Assembly of Maryland we had a bill introduced prohibiting shipment or sale at any season of the year and providing for the taking of bass only by means of rod, hook and line. Owing to the opposition of commercial fishermen, we finally secured only sufficient legislation to cover the prohibition for four months, namely: April, May, June and July, which comprise the spawning season. During those months black bass may not be taken or sold in any manner, whether caught within or without the State. I recommend legislation prohibiting the shipment of black bass out of any State and their sale within any State, and permitting their capture only by means of rod, hook and line at any time.

MR. J. A. RODD (Canada): I should like to endorse, so far as Canada is concerned, the sentiments expressed with respect to the necessity for Federal legislation and Federal control. We feel in Canada that in a great many instances international legislation and control is equally important. To cite a few instances, I may mention the fisheries of the Great Lakes, the Fraser River and Puget Sound sockeye salmon fishery, and the halibut fishery of the North Pacific. The situation in regard to the halibut fishery is covered in the last copy of the Transactions of this Society. Conditions are rather hopeful in regard to the Fraser River and the Puget Sound fisheries, but I do not think those who attended the conference at Lansing can feel that the situation with regard to the Great Lakes is as hopeful. I simply advocate Federal and international legislation and control.

PRESIDENT CULLER: There seems to be a growing sentiment, Mr. Rodd, that there will be something accomplished along that line, possibly an international treaty affecting the Great Lakes fisheries.

MR. RODD: In connection with the Great Lakes fisheries a commission was appointed by the Treaty of 1908 and international regulations were arranged, not only for the Great Lakes but for all waters contiguous to Canada and the United States. Our Government may at any time, by proclamation, put those regulations into effect.

MR. J. L. WICKS: While I have not given any particular study to the legal proposition as to the protection of black bass, it seems to me that any Federal

legislation would have to be limited to the matter of interstate shipments. It does not seem to me it would be competent for Congress to prohibit the sale of bass within State boundaries. The Federal Government has complete jurisdiction over interstate commerce and consequently can prohibit shipment from one State to another, but the protection of bass within the State depends upon the action of the individual States.

Mr. LeCompte: My suggestion was that the States prohibit the sale or shipment from the confines of the State, or within the State; and that the Federal Government follow with the Hawes law, which is at present on the statute books and which has been amended and again introduced by Mr. Hawes at the present session, so as to provide that the Federal regulations should prohibit interstate shipments.

Mr. P. Viosca (Louisiana): Would that prohibit interstate shipments of black bass raised in captivity?

Mr. LeCompte: Not for propagation purposes.

Mr. Viosca: What about bass raised for food purposes in captivity?

Mr. LeCompte: That is usually handled under permit issued by the State. The majority of the States have propagation permits for fish in captivity.

Mr. Viosca: I have reference to the sale for food in other States.

Mr. LeCompte: If you are going to ship black bass out of the State you might as well let the bars down and have no legislation at all on the subject.

Dr. Emmeline Moore (New York): I wonder if Mr. Rodd is prepared to put a constructive statement before the members of this Society, since Canada under this law of 1908 has power to act at any time.

Mr. Rodd: I attended the conferences at Lansing and followed the discussions and the points of view that were expressed by the different State officials. The stumbling block seemed to be the lack of agreement between the States. In some of the States there are as many as five or six executive bodies administering those fisheries, and in very few instances are the regulations similar. The first step would be for the various States to get together. On the Canadian side there is only one province that is interested, and there is only one executive to deal with. Anything in the nature of a treaty should be made by the Federal Government.

Mr. C. Avery: I think Mr. Rodd has designedly omitted saying something in respect to this matter that might be construed as a reflection upon a friendly neighbor. It seems to me that we might as well admit our own remissness in this matter. The United States Senate failed to approve the treaty which was drafted and accepted by Canada, and under which their regulations have been prepared. The United States Government failed to do its part, owing to the disagreements to which Mr. Rodd has referred. That is my recollection of the history of the affair, and I hope Mr. Rodd will correct me if that is not so. The treaty is still subject to approval by the United States Senate, if it is still suitable; but it was drafted so many years ago that it may be necessary to have it revised to bring it up to date. Today's program on the subject of the Great Lakes fisheries has a direct bearing on the point raised by Mr. Rodd, and we

are hopeful that something will evolve whereby the United States will do its part in bringing about this co-operative regulation of the Great Lakes fishery, which requires a treaty accepted by both countries. We have failed to do our part in adopting the treaty.

MR. RODD: Since Mr. Avery has brought the matter up, I may say that as soon as the regulations were formally agreed to by the representatives appointed under the treaty, they were approved by the Canadian Government at the next session of Parliament.

APPOINTMENT OF COMMITTEES

Resolutions: Dr. Emmeline Moore (Chairman), Dr. David L. Belding, G. C. Leach, I. T. Quinn, Judson L. Wicks.

Auditing: T. Surber (Chairman), W. T. Thompson, A. B. Cook, Guy Amsler.

Nominations: Eben W. Cobb (Chairman), H. L. Canfield, F. A. Westerman, Percy Viosca, N. A. Cook.

Time and Place: E. Lee Le Compte (Chairman), G. W. McCullough, Guy Amsler, Dr. H. S. Davis, J. A. Rodd.

Program: Carlos Avery (Chairman), Dr. H. S. Davis, Dr. Emmeline Moore.

International Relations (special): F. A. Westerman (Chairman), T. Surber, B. O. Webster, George Berg, Dr. E. Moore, Nathan Buller, E. L. Wickliff, J. A. Rodd, Dr. W. J. K. Harkness, D. J. Van Oosten.

REPORTS OF STANDING COMMITTEES

REPORT OF THE COMMITTEE ON FOREIGN RELATIONS

By MR. LEWIS RADCLIFFE, *Chairman*

Your Committee views with satisfaction the progress being made in the settlement of international fishery questions, the development of adequate programs of fish husbandry and the closer working arrangements between the authorities in Canada and the United States.

Halibut Commission

With respect to the International Fisheries Commission provided for under the Northern Pacific Halibut Convention, very satisfactory progress has been made by the scientific staff and as a result of their findings steps are being taken to have a new treaty drawn and ratified which will enable the two governments to check the rapid depletion of the older banks and enable the

Commission to secure data necessary for studies of the condition and trend of the fishery.

Sockeye Salmon Treaty

On March 27, 1929, the Secretary of State and the Canadian Minister at Washington signed a treaty for the preservation and extension of the Sockeye Salmon fisheries of the Fraser River system, which includes the waters contiguous to the State of Washington and the Province of British Columbia.

This treaty provides for an International Fisheries Commission of six members. The Commission is charged with the duty of making thorough investigations and is given power to maintain hatcheries and develop the fisheries; to establish a closed season from June 1 to August 20, and to regulate the character and size of fishing. The Convention is concluded for a period of 16 years, after which it is subject to termination on notice of one year given by either government. It is the first treaty signed on behalf of the United States with a resident Canadian Minister at Washington. For the future welfare of the Sockeye Salmon fishery of the Fraser River, it is important that this treaty be ratified.

The International Pacific Salmon Investigation Federation was established in the spring of 1925, as an informal organization of the leading fishery executives of the United States, Canada, the Pacific States, British Columbia and Alaska, for the purpose of co-ordinating and systematizing the work of salmon research according to a comprehensive unified program. This move has been very successful in developing a program of co-operation between the several agencies and regular meetings are held for continued co-ordination of effort.

In the Great Lakes area, the acute fisheries situation continues to attract a great deal of attention. The third meeting of the International Fisheries Conservation Council of the Great Lakes was held at Lansing, Michigan, on December 5, 1928, at the call of Governor Fred W. Green, who has fearlessly tackled the problem of conserving Michigan's natural resources. These conferences have made many important recommendations to the States for the betterment of fishery conditions. In not all of the States have the Legislatures put into effect these recommendations, which is unfortunate in view of the division of authority over the several lakes. A comprehensive program of fisheries investigations is being carried out by the Bureau of Fisheries in Lake Erie and the hydrobiology of the lake and other biological studies are being pushed forward under a co-operative program between States, Provincial, municipal and institutional agencies.

The North American Committee on Fishery Investigations organized at the suggestion of Canadian officials, held its first meeting at Montreal, Canada, June 28, 1921, with representatives from Canada, Newfoundland and the United States in attendance. The most recent meeting (15th) was held at Toronto, Canada, October 22, 1928. Out of these meetings there has developed a coordination of the fisheries investigations of the several governments, a standard-

ization of method and the initiation of scientific researches bearing directly on the economic problems of the fisheries.

In conclusion your committee recommends:

(1) That the American Fisheries Society adopt a resolution strongly urging the ratification of the Sockeye Salmon treaty.

(2) That this Society express its confidence in the work of the International Fisheries Commission provided for under the Northern Pacific Halibut Convention, and recommend studied consideration and prompt action on such recommendations as it may make to prevent the further exhaustion of the important Pacific halibut fishery.

(3) That this Society adopt a resolution strongly urging the several States bordering the Great Lakes to take positive and prompt action on the recommendations made at the meetings of the International Conservation Council of the Great Lakes held at Lansing, Michigan, in order that these fisheries may be saved from exhaustion and urge that provision be made for the extension of the scientific program of fishery investigations now in progress in Lake Erie to the rest of the Great Lakes.

President Culler: It would seem that the recommendations made by the Chairman of the Committee on Foreign Relations might have a tendency to bring the several States together. The recommendations of Mr. Radcliffe will be referred to the Resolutions Committee.

Mr. W. T. Thompson (Montana): I suggest that the representatives of the interested State Commissions meet informally with Mr. Rodd and talk this matter over before the Resolutions Committee acts.

REPORT OF COMMITTEE ON RELATIONS WITH NATIONAL AND STATE GOVERNMENTS

By Mr. W. A. Clemens

Possibly because the Chairman happens to be a Canadian, your Committee is apparently unanimous in feeling that some expression of endorsement should be given of the steps that are being taken to bring about more extensive and closer International co-operation in fishery administration and investigation.

On the Atlantic Coast, on the shores of the Great Lakes and on the Pacific Coast, the men of Canada and United States are earnestly conferring in the attempt to arrive at sound principles for the conservation of our fisheries. On the Atlantic Coast, the North Atlantic Fishery Committee meets annually, alternately in United States and Canada, for the purpose of conferring upon results of investigations carried out according to a program previously agreed upon. Studies of mackerel, cod and haddock are being prosecuted as well as an extensive oceanographical investigation in relation to the problems of fisheries.

In 1927, a conference of the officials of the eight States bordering the

Great Lakes, Canada and the U. S. Bureau of Fisheries was held at Lansing, Michigan, for the purpose of considering steps necessary to be taken for the conservation of the Great Lakes fisheries. A permanent organization was set up known as the International Fisheries Conservation Council of the Great Lakes. At two subsequent meetings in 1928, agreement was reached in many matters relating to uniform regulation of commercial fishing and recommendations are being made to the respective legislative bodies. Also in 1928, a conference was called at Cleveland, Ohio, for the initiation of a comprehensive plan of international co-operation in the scientific investigation of the Great Lakes fisheries. As a result great impetus was given to this phase of the situation and much progress has been made in the study of Lake Erie problems.

On the Pacific Coast there has also been evident an earnest desire for international co-operation. In 1924 United States and Canada signed a treaty for the purpose of attempting to conserve the halibut fishery of the North Pacific. The Commission set up by this treaty realized the necessity for accurate information and organized a scientific investigation which is being carried out with energy and thoroughness.

The need for co-operation in the conservation of the salmon fishery of the Pacific Coast has been felt for many years and while some efforts to secure co-operative action in specific cases have been abortive, yet those efforts to bring about a clearer understanding of the problems common to all sections of the coast have been highly successful.

There was formed in 1925 an International Pacific Salmon Federation consisting of administrative officers and scientific investigators. This organization meets at least once a year and discusses frankly various problems, reviews results of investigations carried out in various areas from Alaska to California, and outlines possible lines of study and regulative action. The Federation has no administrative powers but is simply a medium for consultation. The scientific men are brought in contact with the practical phases and the administrative men with the scientific and both benefit thereby.

Mention of co-operation with respect to the conservation of Pacific salmon would not be complete without reference to the problem of the sockeye salmon of the Fraser River. A treaty pledging joint action for the rehabilitation of the sockeye fishery of this river has been signed by representatives of Canada and the United States and now awaits ratification by the legislative bodies of these two countries.

Thus from Atlantic to Pacific there is an ever-increasing movement toward friendly international conference and co-operative action.

This Society itself is international in organization and in outlook and for over half a century has promoted international goodwill in fishery matters. In this brief statement your Committee desires to call the attention of all the members of the Society to the present encouraging situation and to recommend that the members, individually and collectively as opportunity presents itself, continue to promote such international action as may be in the best interests of fishery conservation.

REPORT OF THE AUDITING COMMITTEE

MR. THADDEUS SURBER: The Auditing Committee have carefully gone over the books and vouchers of the Treasurer and find everything in correct order as submitted in his formal report. The balance in the general fund as of September 1, 1929, amounts to $633.51.

It will be remembered by this Society that a resolution was submitted and passed at the Seattle meeting last year authorizing the Secretary to expend for clerical assistance the sum of $150 annually. For some reason or other, no record of the approval, or disapproval, of this resolution was recorded. Consequently, the legality of complying with the evident wishes of the Society was impossible.

We, therefore, recommend that the sum of $150 per annum be allowed the Secretary-Treasurer for clerical assistance during the year 1928 and a like sum be authorized for the year 1929.

The adoption of the report was moved and carried.

REPORT OF THE COMMITTEE ON RESOLUTIONS

DR. EMMELINE MOORE presented the resolutions, as follows:

Great Lakes Fisheries

The American Fisheries Society recognizes the existence of the various fisheries conservation problems common to the United States and Canada and recommends the immediate adoption of appropriate treaties looking towards the control of the international fisheries, particularly those of the Great Lakes and other inland boundary waters; the adoption of uniform regulations where such are desirable; and closer co-operation in the consideration of such problems. It is further recommended that a copy of this resolution be presented to the following bodies and officials:

To the Minister of Marine and Fisheries, Ottawa
To the Minister of Mines and Fisheries, Toronto
The Secretary of the Department of Commerce, Washington
And to U. S. Senators of the States affected.

It further recommends that, whereas, the fisheries of the Great Lakes are threatened with exhaustion, thus destroying an important source of food and recreation for our people and the investment of those engaged in the commercial fisheries:

"Therefore, Be It Resolved, That this Society urges the adoption of the principle that in all fisheries legislation each species of fish be afforded such protection as will make certain that only fish which have spawned at least once shall be included in the commercial market catch."

"It further recommends that in the adoption of closed seasons, these shall be seasons closed to commercial fishing and that the several States, the Province of Ontario, and the United States Bureau of Fisheries shall take over the collection of spawn for the hatcheries, limiting fishing strictly to the needs of the Federal, Provincial and State hatcheries.

It further recommends that, whereas, the statistics on the commercial fisheries of the Great Lakes have not been adequate to show the trend and the present status of the fisheries:

Be It Resolved, That this Society recommends the adoption by all the governments concerned of the uniform system of collecting fishery statistics proposed

and recommended by the International Fisheries Conservation Council of the Great Lakes convened at Lansing, Michigan, February 8, 1928.

Be It Further Resolved, That a copy of these resolutions be sent to the Conservation Departments of all the governments concerned.

National Park Standards

The Committee endorses the Declaration of National Park Standards as devised and adopted by the Camp Fire Club of America in its statement entitled "National Park Standards," of April, 1929.

Pollution of Lakes and Streams

Whereas, the pollution of our lakes and streams is one of the greatest enemies of fish life, and,

Whereas, with the growth of population and industry the contamination of our public waters is, year by year, increasing, and,

Whereas, the science of sanitation offers in the case of domestic sewage and most industrial wastes a practical and reasonably economic method of treating the same so as to prevent serious pollution,

Now, Therefore, Be It Resolved, That it is the sense of this meeting that all communities should be urged to install plants for the treatment of their liquid wastes.

Be It Further Resolved, That the Izaak Walton League of America and other organizations engaged in the warfare against pollution be, and the same hereby are, extended the hearty encouragement of this Society.

Enforcement of Black Bass Law

Whereas, the black bass is recognized as one of America's most desirable game fishes, and,

Whereas, a Federal act known as the Hawes Black Bass Law was passed by Congress in 1926 in an effort to stop interstate traffic in these fishes, and,

Whereas, the present law provides no machinery for the enforcement of this act, with the result that many tons of these game fishes find their way to the markets in various States,

Therefore, Be It Resolved, That the American Fisheries Society in convention assembled this eleventh day of September, 1929, strongly urges the early enactment of the Hawes Bill, providing for adequate funds and an agency for the enforcement of the Act of 1926, which is now pending before Congress, in order that the Hawes Act may be made more effective.

Be It Further Resolved, That we urge all States to enact laws prohibiting the taking and sale of black bass except for propagation purposes regardless of where taken.

The Oyster Industry

The American Fisheries Society in 59th Annual Convention assembled in Minneapolis, September 11, 1929, takes cognizance of the oyster industry of the United States as being one of great economic importance.

The proper development of the industry and its encouragement should not only engage the attention of the several coastal States having such industry, but because of the national contribution of a wholesome and nutritious food supply to our people it makes, the industry should meet encouragement also from the Federal Government, and safeguards should be thrown around the industry that nothing should stand in the way of its highest development.

In order that the oyster industry may be properly, wisely and more effectively stimulated in the United States and because of the industry's great economic importance, it is believed that the importation of canned oysters of inferior grade to those of our own from foreign countries placed free of duty

on American markets, will not only greatly hinder, but tends to destroy the industry.

Therefore, Be It Resolved, That it is the sense of the American Fisheries Society, that the National Congress should throw such safeguards around the oyster industry of the United States as will guarantee to it a normal, healthy development as a medium through which not only thousands of our citizens may be gainfully employed, but millions of them fed with a wholesome, palatable and nutritious food supply.

Be It Resolved Further, That the Secretary of the American Fisheries Society be, and is hereby, instructed to forward a copy of this resolution to the proper authorities at the National Capitol in Washington, D. C., for their information and consideration.

Acknowledgment of Courtesies

For the attractive program which has characterized its 59th Annual Meeting, the American Fisheries Society expresses its deep appreciation to the various local organizations which have contributed so completely and effectively to its entertainment.

We therefore extend our sincere thanks to the Minnesota Game and Fish Commission for its efficient services in the form of entertainment, programs, clerical services and badges, which have contributed so much to the success of the meeting; to the Hennepin County Sportsmen's Club, the Outer's Club and the Minneapolis Chapter of the Izaak Walton League for entertainment; to the Hon. William F. Kunze, Mayor of Minneapolis, and to his Excellency, Theodore Christianson, Governor of Minnesota, for their deep and appreciative interest in the aims of the Society; to Dr. William J. Mayo, the United States Bureau of Fisheries, and the United States Biological Survey, for entertainment during the excursion on the Mississippi River; to Dr. Thomas S. Roberts of the University of Minnesota for the use of the Museum of Natural History as a place of meeting; to the Minneapolis Civic and Commerce Association for its assistance and co-operation; to the Minneapolis newspapers for the publicity given the meeting; and to the management of the Nicollet Hotel for the many courtesies extended which have contributed greatly to the comfort and pleasure of our members and to the success of the convention."

Dr. Emmeline Moore moved the adoption of the resolutions.

The motion was seconded by Mr. E. L. LeCompte and carried unanimously.

REPORT OF THE COMMITTEE ON INTERNATIONAL RELATIONS

Mr. F. A. Westerman, *Chairman*

The Committee on International Relations met with the Committee on Resolutions in drafting a resolution with reference to the fisheries of the Great Lakes which was incorporated in the report of the Resolutions Committee and was presented by Dr. Emmeline Moore, Chairman.

On motion of Mr. E. L. LeCompte, seconded by Mr. I. T. Quinn, the report was adopted.

REPORT OF COMMITTEE ON TIME AND PLACE

Mr. E. L. LeCompte: I have had the pleasure of serving on the Time and Place Committee on numerous occasions, and it would seem that the joint con-

vention of the two Associations is becoming internationally known, judging by the number of requests for our presence for the coming year. I think we have had more invitations this year, from widely scattered points, than in any previous year. After careful deliberation, the Committees of the American Fisheries Society and of the International Association have decided unanimously that the convention shall meet in Toronto, Canada, in 1930. Mr. Quinn, Chairman of the International Committee on Time and Place, will anounce the dates of the meeting.

MR. I. T. QUINN: We decided on the time as the last week in August, 1930, beginning on Monday and running through the week. One reason for our deciding upon this time was that we people from the far south want to strike this section in the summer time. Another reason is that the Canadian National Exhibition will be in progress at Toronto during that week, and it will give us an opportunity to see something of Canada. The Deputy Minister, Mr. McDonald, has his annual exhibit of wild life and fisheries resources, which we understand is one of the finest exhibitions of wild life resources on the American continent.

I move the adoption of the report of the Time and Place Committee.

The motion was seconded by Dr. Davis and carried unanimously.

REPORT OF THE COMMITTEE ON NOMINATIONS

MR. EBEN W. COBB: The Committee on Nominations offers the following report:

President, DR. DAVID L. BELDING.................................Boston, Mass.
Vice-President, E. LEE LECOMPTE.............................Baltimore, Md.
Secretary, CARLOS AVERY...................................New York, N. Y.
Treasurer, CARLOS AVERY...................................New York, N. Y.
Librarian, JOHN W. TITCOMB.................................Hartford, Conn.

Vice-Presidents of Divisions

Fish Culture, CHARLES O. HAYFORD.........................Hackettstown, N. J.
Aquatic Biology and Physics, WM. J. K. HARKNESS.............Toronto, Ont.
Commercial Fishing, PERCY VIOSCA, JR.....................New Orleans, La.
Angling, FRED A. WESTERMAN..................................Lansing, Mich.
Protection and Legislation, I. T. QUINN....................Montgomery, Ala.

Executive Committee

M. C. JAMES, *Chairman*....................................Washington, D. C.
C. R. BULLER...Mount Pleasant, Pa.
C. P. PETERSON..Bisbee, N. D.
JOHN P. BABCOCK...Victoria, B. C., Canada
W. E. ALBERT...Des Moines, Iowa
GUY AMSLER..Little Rock, Ark.
CHAS. R. POLLOCK...Seattle, Wash.

Committee on Foreign Relations

Henry O'Malley, *Chairman*............................Washington, D. C.
H. S. Davis..Washington, D. C.
Wilbert A. Clemens..............................Nanaimo, B. C., Canada
William C. Adams..Boston, Mass.
Frederic C. Walcott......................................Norfolk, Conn.

Committee on Relations with Foreign and State Governments

Lewis Radcliffe, *Chairman*............................Washington, D. C.
J. A. Rodd...Ottawa, Canada
B. O. Webster...Madison, Wis.
H. B. Ward...Urbana, Ill.
Geo. W. McCullough..St. Paul, Minn.
John Van Oosten..Ann Arbor, Mich.

Committee on Publications

David L. Belding..Boston, Mass.
John W. Titcomb...Hartford, Conn.
Geo. C. Embody...Ithaca, N. Y.
H. S. Davis..Washington, D. C.

Mr. E. W. Cobb moved the adoption of the report, seconded by Mr. Hesen. The motion was carried unanimously.

Retiring President Culler: I will appoint Mr. Tucker and Mr. Westerman to escort the newly elected president to the chair.

President-Elect Belding: Fellow members, I appreciate very much the honor which you have bestowed upon me, and I sincerely trust that I may be able to follow worthily in the footsteps of my distinguished predecessors.

Whereupon the 59th Annual Meeting of the American Fisheries Society was adjourned to meet in Toronto, Canada, in August, 1930.

In Memoriam

James Annin

John N. Cobb

Fred H. Doellner

Dr. Dana J. Leffingwell

George N. Mannfeld

Dr. Jan Metzelaar

E. L. Whittemore

J. Von Lengerke

E. A. Tulian

J. E. Pflueger

S. P. Wires

PART II

PAPERS AND DISCUSSIONS

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STATUS OF THE GREAT LAKES FISHERIES

By Lewis Radcliffe

Deputy Commissioner, U. S. Bureau of Fisheries

Along our northern boundary is a chain of five great lakes with a combined area of over 95,000 square miles. These occupy a group of very deep valleys, all excepting Erie, having a depth in excess of 600 feet. The waters are very cold, never rising above 39 degrees at depths of 350 feet. The primitive character of the lakes and the great depth and very cold water of all except Erie, quite definitely circumscribe their productivity and create a necessity for a carefully developed program of fish husbandry to prevent the exhaustion of their fishery resources, and maintain productivity on a commercial scale.

In the days of the early settlers these lakes were well stocked with fish of most excellent quality. Considering the intensity of fishing operations, the lack of adequate regulations and the changes in shore conditions from industrialization, productivity has been maintained at a surprisingly high level. Recent investigations disclose a situation of such a critical character as to arouse grave alarm over the future of the fisheries. This in turn has resulted in the development of a co-operative program of research of wide scope and of closer study by the legislative and executive branches of the various governments concerned, to provide much needed restrictions on fishing operations.

Importance of the Fisheries

During the past sixteen years (1913-1928), the combined annual catch of the Great Lakes fisheries (United States and Canada), has ranged between 100 and 150 million pounds. The fisheries have furnished employment to 15,000 fishermen who received about $10,000,000 annually for their harvest. They have been a source of recreation to thousands of our people. Their central location far removed from the coastal sources of supply of fish greatly enhances their value as a source of food in peace and war times. The investment in the commercial fisheries exceeds $15,000,000. They add to the wealth of the shore communities not less than $5,000,000 yearly through providing transients with lodging, boats, bait, gasoline, etc. The Great Lakes fisheries are, therefore, a great natural resource which should be husbanded and not despoiled.

Trend of the Fisheries

Between 1913 and 1925, the catch averaged over 122 million pounds a year, of which the United States' share was 86 million and Canada's 36 million, a difference of 50 million pounds. This difference is accounted for in part by the fact that Lake Michigan lies wholly within

the United States. From 1918 to 1925, the catch declined from 150 to 100 million pounds, a decline of one-third in eight years. The United States catch declined from 107 to 70 million pounds, a decline of 34½ per cent. The catch of Canada fell from 43 to 31 million pounds or 28 per cent. Considering the economic importance of the fisheries as described in the previous paragraph, it is a matter of grave concern that so great a resource should be jeopardized.

Extermination of Some Species a Possibility

The deeper waters of the lakes are inhabited by species of chubs (deep-water herring), some of which have only recently been described. Seven species occur in Lake Michigan and six in Huron, five in Superior, three in Ontario and none in Lake Erie. The restricted range and the probable very slow rate of growth of each of the commercial species makes it susceptible of being completely exterminated unless the stock is carefully safeguarded.

Of the general situation Dr. Koelz states: "While in certain localities the pursuit of the remnants of certain species has so fallen off as to allow them to maintain their numbers or even to increase somewhat, in general, the situation cannot be viewed with satisfaction. We are faced with the extermination of the sturgeon in all the lakes, of the bluefin in Lake Superior, the blackfin in Lake Michigan, and the bloater in Lake Ontario, and with the reduction of the whitefish from first place in abundance in 1880 to fourth place in 1922, with that place contested closely by the sucker, which was in 1880 not considered worth the catching."

Resume of Principal Efforts at Husbandry

Concern over the fisheries of the Great Lakes, if I recall correctly, was one of the factors that influenced the forerunner of the American Fisheries Society to urge upon Congress the establishment of the U. S. Fish Commission, now the U. S. Bureau of Fisheries. One of the first of the general surveys made by the newly created Commission was that of James W. Milner, Assistant Commissioner of the U. S. Commission of Fish and Fisheries, who made a general survey of the Great Lakes fisheries in 1871 and 1872. Milner "visited many fishing localities, gathered testimony of the fishermen as to the condition of the fisheries, its comparison with former years, the kinds of nets in use and their effect on the numbers of fish and the opinion of the net-owners on the influence of protective legislation," says Dr. Van Oosten. In fact, he points out that Milner's discussion of proposed protective legislation made 50 years ago might be bodily incorporated in a 1928 report with but slight modifications. This is truly significant in the light of the lack of an adequate program of fish husbandry during the half century that has since elapsed.

Rathbun and Wakeham, appointed as a Joint Commission by Great Britain and the United States, made a very complete survey of the boundary waters fisheries, 1893-1896. They were called upon "to consider and report on the regulations, practice, and restrictions proper to be adopted in concert on the—

(1) Limitation or prevention of exhaustive or destructive methods of taking fish.
(2) The prevention of pollution or the obstructing of waters to the detriment of the fisheries.
(3) The adoption of uniform closed seasons.
(4) The adoption of practical methods of restocking and replenishing the waters with fish."

Also making specific recommendations for each lake. In the event of joint action by the two governments they urged that provision be made for a permanent joint commission of experts, charged with direct supervision of the fisheries and empowered to conduct necessary investigations, and to institute such modification in the regulations as might be found necessary from time to time. Their excellent summation of the situation is worthy of repetition—

"That a uniform system of regulation common to the entire extent of each body of water along the boundary lines is required to insure the protection of its resources, is fully shown by the conditions which we have found to exist in nearly all of them, whether bordered on the side of the United States by a single State or by several States. The failure to secure adequate results in that direction has naturally been due to the diversity of legislation, but it has resulted in large part from the general lack of accurate information regarding the habits of the several fishes to serve as a basis for intelligent action. While we have been able to establish some important facts respecting the natural history of the commoner market species, much more remains to be accomplished in that regard, and the subject should be given due prominence in the future." How do you explain the lapse of more than a quarter of a century before serious effort was made to carry out these recommendations?

In 1908, under the direction of Dr. David Starr Jordan, the International Fisheries Commission instituted a survey primarily to acquire data to serve as the basis for a code of international fisheries statutes to supplant those of the Canadian provinces and the several states. Failure of the United States Senate to ratify the agreement again spelled a further period of inactivity relative to the proper husbandry of the Great Lakes fisheries.

Hampered by inadequate funds for the conduct of fisheries research, but impressed by the need for the conduct of studies of the fisheries

of the Great Lakes, the Bureau instituted a small program of research in 1917. Dr. Koelz who was in charge of this work for much of this period, in a report published in 1926, made the following recommendations:

1. "The needs of the Great Lakes fisheries should be studied and in the light of the knowledge gained regulations, having for their object the conserving of the fisheries, should be created. We already have data to show that no single law can be devised to meet the varying conditions presented by one lake, to say nothing of applying one law to several of the lakes. The application of any laws found advisable must be independent of political boundaries. The present division of authority over the fisheries among several states impedes the enactment and complicates the administration of any legislative provisions, and it is therefore urgently recommended that some definite and responsible organization, international in character, be provided through which a co-ordinated control of the fisheries may be secured.

2. "The closed season to protect spawning fish should be restored wherever practicable, and no spawn should be collected if investigations and experiments fail to establish the desirability and effectiveness of propagation.

3. "Investigations to determine the life histories of the important species already begun should be continued, and statistics reflecting the condition of the fisheries should be collected from year to year to supplement these studies. Only by means of such statistics, interpreted in the light of life-history facts, can the fishing industry be intelligently controlled."

The falling off in the catch of 50,000,000 pounds from 1918 to 1925, awoke the fishing industry to a realization that action was necessary if commercial fishing operations were to be continued. State executives responsive to the demands of their constituencies began to show an enlivened interest in the conservation of the Great Lakes fisheries.

On February 16, 1927, there was held at Columbus, Ohio, a conference called by Governor Vic Donahey to secure co-ordinated action for the conservation of the fisheries of Lake Erie. At this conference there was formed the Lake Erie International Conservation Council. Resolutions were adopted to become effective when each State bordering Lake Erie and the Province of Ontario should adopt them. This involved five governmental agencies directly. This was the first and only meeting of the Council.

On March 3, 1927, at Lansing, Michigan, there was held a conference of fishery officials from the states bordering the Great Lakes and the United States Bureau of Fisheries, called together by Governor Fred W. Green of Michigan to consider ways and means for conserving the fisheries of the Great Lakes. A comprehensive set of regu-

lations governing fishing gear, sizes of fishes and the taking of spawn were approved by the conference but with the old insurance to continued inactivity that they should not become effective until all the governments (State and Provincial) bordering a given lake had adopted them. On the whole, however, the conference represented a distinct advance recommending compulsory saving of spawn, control of pollution, the collection of uniform fishery statistics by the individual states, and the vesting of greater authority in the Executive branches of the government to promulgate and enforce additional fishery regulations found needful. At this meeting there was formed the International Fisheries Conservation Council of the Great Lakes and authorization that meetings be held annually or oftener approved. Despite the lethargic attitude of most of the state legislatures toward rendering its recommendations effective, the Council has accomplished much. Subsequent meetings were held on February 8 and December 5, 1928, in each instance at the call of Governor Green, who has fearlessly and vigorously tackled the problem of conserving Michigan's natural resources.

One incident at each of these conferences is especially worthy of mention. At the February 8th meeting, the Honorable E. F. Sweet, formerly an assistant Secretary of the Department of Commerce, commenting on the difficulties of securing immediate action said: "We noticed when I was connected with the Department that where a state was divided from another state by a river and one state had better laws on the problems of the fisheries than the other had, the state that had the lowest grade of regulations set the pace. . . If we could be big enough to leave the whole subject of the fisheries of the Lakes to the Federal Government, and could induce our State legislatures to abandon their control on this matter and adopt the measures recommended by the Federal Government, I believe that in the long run we would be a great deal better off than we are now at present and have been in the past. The Federal Government has the means and the intelligence and, so far as I am aware, is free from any bias except what is best for the people of the United States; not Ohio, not New York or Pennsylvania or Michigan, but for all the States. I have every reason to believe that their handling of this subject would be upon a high basis that would conform to that definition of conservation—making the greatest possible use of the fisheries of the Lakes that is consistent with the interests of the future."

In closing the third conference December 5, 1928, Governor Green said in part—"This is a work that has to be done, and if we can do it among ourselves, the States, it isn't necessary for Washington to take a hand in it. . . And, yet, if we do not do this work ourselves it will have to be done at Washington. If they do it at Washington in their way, we will never get it back in our hands again. I hope that you will

go back to your States and get back of a bill that will be formulated along these lines. If you do that you shall have done a real service for your country."

These actions undoubtedly stirred the States to the need for action as more constructive fishery legislation was passed in 1929 than in the previous decade, Michigan taking the lead. Several of the States will have to show a more receptive mood toward real conservation, if the threat to take the matter out of State hands is to be removed.

Coincident with the holding of these conferences, there has developed a program of co-operative fisheries research particularly with respect to Lake Erie. A conference of the various biologists interested, called by Commissioner O'Malley, was held at Western Reserve University, Cleveland, Ohio, on February 6, 1928. This was well attended and greatly stimulated research work with the result that there has been set up a comprehensive co-ordinated program of fishery research which is being actively pushed. An increase of $10,000 in the Bureau's appropriations beginning with July 1, 1927, has made possible a much needed expansion of its work, with the result that in due time we will know with greater definiteness what regulations are necessary for the proper husbandry of these great natural resources.

During the past two years the Bureau has taken an active part—

(1) In the unification and co-ordination of the scientific work on Lake Erie.

(2) In inaugurating a new system of fishery statistics suitable to the needs of the biologist.

(3) In the codification and revision of the commercial fishing laws of Michigan, Indiana and Ohio, in co-operating more closely with State authorities and fishermen's organizations to secure specific and uniform laws for each lake.

(4) In inaugurating a series of studies—
  a. On the effect of gear on the fish population.
  b. On fish populations instead of individual species.
  c. On fluctuations in the fisheries.
  d. On life histories of nine important market species.

Division of Authority

In reviewing the history of the Great Lakes fisheries, as a basis for working out a program of fisheries administration, one must bear in mind the division of authority. Jurisdiction is divided among 8 states and a Canadian Province. The questions are not alone state, but

national and international. Jurisdiction over Lake Michigan is divided between four states; that over Lake Erie between four states and the Province of Ontario. Such division of authority makes concerted action most difficult.

Effects of Pollution Over-Estimated

Because the rapid decline in the catch between 1918 and 1925 was largely attributed by many to pollution, the results of actual investigation merit mention.

The results of an investigation made by the Division of Fish and Game of Ohio in August 1926 to learn how far out from the lake-shore cities, sewage pollution may occur in sufficient quantity to affect the fish supply directly or indirectly disclosed that "there was no serious contamination of the open lake in deeper water, or very far from sources of pollution in shallower waters along shore."

In 1928, a survey made at the eastern end of Lake Erie "showed that there were localized areas where trade and domestic wastes caused considerable contamination of the waters, but in no case did this extend far from the source. With the exception of the polluted areas, the lake was found to have no chemical conditions considered detrimental to the normal existence of organisms."

"In general, the results of these investigations show nothing in the physical, chemical and biological conditions of Lake Erie to explain the present depleted state of the commercial fisheries."

In conclusion, it may be stated that satisfactory progress is being made in fisheries science in Lake Erie to serve as a proper basis for the husbandry of the fisheries of that lake. This program of research should be extended to the other lakes as promptly as possible.

Secondly, some of the State legislatures have risen to the needs of the times and have passed forward looking legislation. Others of the States have failed to keep pace with the exigencies of the situation. If these States can be brought to realize the seriousness of the situation and to act accordingly, it should be possible for the States to continue to handle the situation.

Discussion

President Culler: Mr. Radcliffe's paper has brought out some illuminating facts as to the depletion of the fisheries of the Great Lakes. The paper is now open for discussion.

Mr. W. T. Thompson (Montana): I believe we ought to get something constructive out of the establishment of a board such as Mr. Radcliffe suggests. We have here representatives of all the interested States and Canada, capable of formulating a report. I move that a committee consisting of representatives

of the interested States and Canada be appointed to act with the Committee on Resolutions so that a proper resolution may be adopted and presented at this meeting.

DR. EMMELINE MOORE: I second the motion. As Chairman of the Resolutions Committee, I think we should have the help that Mr. Thompson suggests in formulating a resolution.

The motion was carried unanimously and President Culler appointed a special Committee on International Relations.

THE TAKING AND CARE OF LAKE TROUT EGGS

By G. W. Hoofnagle

Acting Superintendent U. S. Fisheries Station, Charlevoix, Mich.

The first thing of importance in the taking of Lake Trout eggs is knowing what equipment is needed and second in importance is going into the field with sufficient equipment to handle the eggs properly. In general the equipment should consist of tin spawning pans about twelve inches in diameter and about four inches deep, one or more quart dippers, several kegs of ten gallon capacity, a small box or pan a little larger than the case trays and two or three inches deep, a few twelve or fourteen quart buckets, a yard or two of scrim, a few pairs of wool gloves or mittens, a thermometer, a few lanterns, some well-made field cases and a tub or two are often handy things to have.

The next important thing is the selection of fish from which the eggs are to be taken. Live fish only are to be considered. If the eggs are to be taken from fish caught in gill nets the fish should look fairly bright and not too dull or pale in color, as there are times, due to rough weather when gill nets cannot be fished every day and the fish must remain in the nets for two or three days at a time, and a pale or washed looking fish would indicate that it had been in the net too long and in its struggle had weakened its vitality and is not able to produce strong eggs. The same is true of the male fish. Therefore both fairly bright male and female fish should be selected. Eggs taken from fish caught in pound nets are likely to be of some better quality for while the fish is in captivity it has much more freedom than the fish in a gill net. Yet, I believe when it is possible to fish gill nets every day and with care in selecting the fish nearly as good a quality of eggs can be produced as from fish caught in pound nets.

When the fish has been selected the next important thing is the proper handling of the fish. With one of the woolen gloves or mittens on the left hand the fish should be caught by the tail and the head placed firmly between the elbow and the body, the wrist is bent so the hand is at about a forty-five degree angle which places the fish in a natural position. If the hand is held straight with the forearm it draws the tail up and the fish is not in its natural position and at the same time it draws the skin tight over the vent and will not permit the free flow of eggs, necessitating more pressure to be used which is injurious to the eggs.

With the fish in the proper position and being held over a spawning pan which has been freshly dipped in water the thumb and forefinger of the right hand are placed back of the gills and with slight pressure and working slowly towards the vent the flow of eggs will start if the

fish is ripe. The fingers should not be run more than half way to the vent then replaced back of the gills again and this repeated until the eggs stop flowing. If pressure is exerted through to the vent the eggs are apt to be broken and a white substance will come from the fish which will interfere with the fertilization besides depositing a lot of shells with the good eggs. The woolen glove or mitten should not be worn on the right hand except in severe cold weather as it carries the slime from the fish into the pan with the eggs. All foreign substance should be kept from the pan as it interferes with the fertilization of the eggs.

The male fish should be handled in the same manner. It is well to use a male with each female, unless males are scarce in which case, if the males are free with milt, one male to two females can be used. A feather should be used to thoroughly mix the eggs and milt or just a little water in the pan and a light circular motion of the pan will mix them. The eggs should be fertilized as soon as taken for if allowed to stand they will begin to "water harden" and fertilization becomes difficult. Soon after the eggs are fertilized they should be washed clean and placed in keg which is half filled with water. In washing eggs the water should never be poured directly on the eggs but poured around edge of pan lightly with a dipper, likewise in transferring eggs from pan to keg the pan should be lowered into the water and tipped up slowly. Eggs roughly washed or poured in keg are apt to be killed, especially eggs that have begun to water-harden. The keg may be filled about half full of eggs which should be slightly stirred with the hand or dipper every five or ten minutes or until the eggs are thoroughly water-hardened. The eggs should be kept in the shade away from heat and the water changed every hour when possible, they then may be packed in cases for shipment.

When packing eggs for shipment a layer of wet moss is placed in the bottom of the case. The trays should be thoroughly dampened before placing any eggs on them. One tray at a time is placed in the small box or pan, which is slightly larger than the tray and which has been filled about two-thirds full of water. The eggs can then be poured lightly without injury on to the tray and the tray then lifted and placed in the case. Care must be taken not to place too many eggs on a tray as the cloth will sag causing too much weight on the eggs in the bottom of the case. Scrim is the best material to use for the bottom of trays because it is open mesh and will allow the water to drain through. If other material is used such as canton flannel it should be well pricked with an ice pick or some sharp pointed instrument before placing eggs on the tray. Material such as canton flannel will not allow the water to drain through, thereby holding the water on the top of the tray and causing the eggs to smother.

Eggs after being packed in the cases should be placed in a cool place out of the sun and wind but not exposed to a freezing temperature, until they can be transferred to the hatchery. If eggs are held in the field for several days they should be dipped each day by filling the box or pan nearly full of water and submerging the trays deep enough to thoroughly wet all the eggs on the tray. The thermometer should be used occasionally so that the eggs can be kept at as even a temperature as possible. After being transferred to the hatchery the eggs should be examined and temperature taken and if temperature of eggs and water in hatchery varies more than two or three degrees the eggs should be tempered gradually so as to be near the same temperature as the water. After eggs have been transferred from the case trays to hatchery trays all dead eggs, egg shells and any other foreign substance which is apt to start fungus should be picked off before the trays are placed in the troughs. Eggs, when being placed in the troughs, should be submerged slowly and evenly distributed over the trays so that a good circulation is obtained. Eggs should not be permitted to "boil up" on the trays.

The handling of eggs should be avoided as much as possible after placing in the troughs until the eye spots appear but when eggs must be handled before the eye spots appear they should be placed in the picking trough and handled as easily and carefully as possible, a feather should be used to stir the eggs and not the fingers or pickers. Eggs after they are eyed should be thoroughly washed and the unfertile eggs immediately picked off.

I have heard it remarked that certain trout eggs had to be thrown on the floor and tramped on in order to kill them. I'll admit some eggs will stand more abuse than others but we should not get the habit of handling eggs roughly just because they will stand it, lest we form the habit and are very apt to handle the more tender eggs in the same manner and then wonder why our results are poor. Sudden jars and rough handling should be avoided at all times during "The Taking and Care of Lake Trout Eggs."

A BRIEF SUMMARY OF WORK OF THE BUREAU OF FISHERIES IN THE LAKE SUPERIOR REGION

By W. A. Cook

Superintendent U. S. Fisheries Station, Duluth, Minn.

The fish-cultural work of the U. S. Bureau of Fisheries on the Great Lakes consists of the artificial propagation of quite a variety of food fishes but as conducted in the Lake Superior region, by the Duluth, Minn. Station, emphasis is placed on Lake Trout, White Fish and Herring, the greater part of the work consisting of the propagation of Lake Trout (Christivomer namaycush).

The territory covered is quite extensive, some years reaching from near the Wisconsin border eastward to within about eighty miles of the Sault Ste. Marie, Mich., varying of course with local conditions. In addition to this long shore line all of Isle Royale, Mich., is also covered, with its length of forty-one miles involving considerable shore line again.

Lake Superior due to its size and geographical position offers a very diversified spawning season for Lake Trout. An early run of these fish starts the very last of September at Isle Royale followed shortly by another run off the northern tip of Keweenaw County, Mich., a distance of approximately fifty miles from Isle Royale. The next run of spawners usually appears at Portage Lake, Ship Canal, Gay, Big Traverse Bay, and Rabbit Bay which are a little farther south, being followed by a run at Huron Island. By the 17th or 18th of October the run is usually in full swing at all collecting stations operated by the Bureau, the most distant of which is only about eighty miles west of the Sault Ste. Marie. Thus it will be seen that this one station has many miles of shore line to cover. To cover this field and keep things running smoothly requires the presence of the station superintendent in the field most of the time during egg collections.

I do not think that any field connected with the collection of Lake Trout eggs provides a larger variety of eggs considering color and size. Eggs of greenish cast, light cream, salmon pink and amber shades, besides several variations of these colors are taken. Often eggs of these various colors are taken from fish caught on the same shoals. The scientific branch of our service tells us that the various colorations may be caused by environment. If this is the case it would be interesting to know why it is that fish of the same species producing various colored eggs are taken on the same spawning shoals.

At many of the smaller egg collecting stations, eggs, after being taken, must be packed and transported by boat to the mainland and thence to

the nearest railroad by truck, at some places a haul of thirty miles. One of the larger collecting stations is situated twenty-five miles from a railroad and all eggs collected must be transported by truck to the railroad station. Notwithstanding the fact that many of the eggs collected have to undergo these various methods of transportation and are carried from one hundred to two hundred and fifty miles by rail before reaching Duluth, the percentage of eggs eyed up runs very good.

The collection of Lake Trout eggs around Isle Royale also provides a very diversified assortment of eggs. Due to the isolated location of many of the fishing ports around the Island, and to the fact that the only method of shipping the eggs to the hatchery is by a boat which carries passengers and freight and makes the smaller stops only spasmodically, the eggs when received are often partly developed and occasionally eyed right on the trays. Thus it will be seen that instead of having green eggs all taken within a few hours we often receive eggs of widely different takes and ages which tax the skill of a fish culturist to handle without injury.

By November 6th almost all field stations are closed with the exceptions of a few places on Isle Royale, Mich. The hatchery water supply at Duluth, derived from a nearby river, drops to 32½ Fh., usually shortly after the last of the egg collecting season and remains at that temperature until the spring "break-up," generally occurring around the middle of April. This makes a prolonged period of incubation but the fish hatched are strong and vigorous from the start, and having absorbed some of the food sac before hatching, develop very rapidly and tax the distribution facilities to the utmost.

The eggs of a salmon pink color produce fry that are readily distinguished from others by the reddish cast of their bodies, while eggs of some of the other varieties mentioned produce fish of as diversified appearance.

Distribution of Lake Trout starts while they are in the fry stage and usually ends with fingerlings No. 1. Due to fact that fish are planted back in the localities from which the eggs are obtained, distribution of this species from the Duluth Station requires long trips on which a messenger often carries 250 cans. All these fish are planted from the decks of boats running under check, fish being poured into a tub placed on deck, with a two inch hose connection passing out into the water so as to introduce fish into the lake without much concussion.

Most of what has been briefly told in this paper is "old stuff" to the fish culturist engaged in Lake Trout work as well as many others present but its real purpose is to bring before you a few outstanding facts in connection with the work which are worthy of mention. First, it would be very interesting to know just why it is that this species

produces eggs of such variable color and size. Some of the eggs are nearly as small as good sized brook trout eggs while others run 3½ to the inch. These facts would lead one to think that there must be several distinct families or sub-species of these fish and possibly the propagation of certain ones would be to better advantage than others. While much money and effort is spent to propagate these fish little is known up to the present time as to their survival after being planted back in the lake. When the fry and fingerlings are planted in the Great Lakes nobody seems to know whether they remain in locality of the plantings, whether there is food enough for fish of that size in the depth of water in which they are planted and many other things which would go far toward making a successful plant. A study of conditions which govern the development of these fry and fingerlings into adult fish and the effect of different lake currents and depths upon the lives of these fish might prove to be of great value also.

Another object of this paper is to show that in recommending legislation affecting commercial fishing on Lake Superior, conditions existing on any of the other Great Lakes should not be taken as a means of determining what laws would best govern fishing on Lake Superior as far as the open and closed seasons are concerned.

At the present time in some localities commercial trolling is practiced and this is rapidly depleting the run of the large spawning lake trout. It is the claim of some of the men using this kind of rig that 90% of the fish caught by this method are female fish and practically all are large ones. This method of fishing must prove very detrimental to fish of this species.

The work of propagating the lake herring on Lake Superior has been attempted at various times but has not proven to be very successful on account of the conditions under which eggs must be secured. At the present time, due to lack of closed season on herring fishing the spawning period is the harvest time for commercial fishing and tons and tons of these fish are taken at this time with resultant destruction of millions and millions of eggs. The tugs set all the nets they can handle and when lifting have a large crew passing the nets back from the lifter and piling them up fish and all. They run under good speed while doing this and even with spawn-takers aboard there is but little chance to get eggs as fish can only be secured while they are passing by in the nets. If these fish were protected like the trout it would do much towards keeping up the supply but with unrestricted fishing it will gradually deplete the supply of this valuable food fish. Eggs which we took off from small skiffs where the spawn-taker was given chance to take the eggs properly proved to be of very good quality.

The spawning period of this species in Lake Superior comes at a time of year (the latter part of November) when the weather is usually

rough and the work of lifting such nets is a hazardous occupation. Nearly every year some of the herring fishermen are drowned. Due to the bad weather conditions prevailing at this time is has been practically impossible to date to interest any of the smaller fishermen in the work of collecting the eggs for artificial propagation even by offering to buy the eggs.

We often hear or read about the wonderful work of various hatcheries in turning out one, two, three or five million brook trout but seldom is it that the general public gives any thought when a hatchery has planted from ten to thirty million lake trout.

Discussion

PRESIDENT CULLER: The two papers on the propagation work of the Great Lakes are now open for discussion. Possibly some of the members could answer Mr. Cook's inquiry regarding the reason for different colorations.

DR. METZELAAR (Michigan): Dr. C. L. Hubbs of the University of Michigan has commenced a study of the sub-species found in the lakes of the Huron Mountain Club, which is located near Big Bay in Marquette County, Michigan. He finds that the different forms of lake trout in these waters cannot be classified as sub-species. He believes that they represent relics of various Lake Superior forms which flourished at some time in the history of these lakes.

DR. VAN OOSTEN (Michigan): Very little work has been done on the lake trout. We do not even know how many species are in the lakes. We know nothing about its history, except that we have some idea of its spawning time. As for the lake trout itself, its life history, growth rate, age, sex maturity, and migration, we know practically nothing. I consider Mr. Cook's paper was an excellent one. He has brought out certain facts that are closely related to hatchery work. Some question may be asked about the variation in the color of the meat. We find trout with white and pink flesh together in certain localities. The difference is probably due to some racial factor. The same is true of the fat trout styled as a race, called Siscowet, which inhabits the deepest parts of Lake Superior. Its being fat may be due to environmental conditions rather than biogenetic differences.

DR. H. S. DAVIS (Washington, D. C.): An explanation has been offered by some European investigators as to differences in the sizes of eggs in fish of the same size, but so far as my observations go in this country, the size of the egg depends largely on the number. A fish of a certain size produces 500 eggs; another of the same size produces 300 eggs; usually the fish with the fewer eggs will produce the larger size. Mr. Dinsmore told me a year or so ago that he was quite certain that the size of the eggs of some of his fish had been influenced by feeding. If he started feeding heavily late in the spring, he got larger but fewer eggs, while if he started feeding heavily after the spawning season he got more but smaller eggs from the same fish. Similar conclusions have been reached by Dahl, in Europe.

Mr. W. A. Cook: In the same district some eggs are extremely large and others very small, and you can notice a wide variation in the fry shortly after they hatch. If problems such as this could be studied by our scientific friends it might be possible to develop a breed of lake trout of a superior type.

President Culler: Has nothing ever been done to establish whether the variations in the fry show in the adult?

Mr. Cook: Not to my knowledge. We do not breed many adult fish.

Dr. Van Oosten: Is there a possible correlation between size of egg and size of fish? It is possible that the smallest females produce the smallest eggs.

Mr. Cook: My evidence is based on hearsay, because all the eggs are obtained from commercially caught fish. The principle variation takes place in the eggs which are secured around Isle Royale and Keweenaw Point. At Marquette the first run or "shoal" trout, considered a smaller fish, produces a fair percentage of the pink eggs.

Mr. B. O. Webster (Wisconsin): Observations on the large lake trout of northern Lake Michigan as contrasted to the smaller fish in the lower part of the fishing area indicate that the large eggs come from the large fish and that the majority of the small eggs are from the small fish. In the southern part of Lake Michigan, around Waukegan, Racine and Kenosha, the fish spawn on clay beds and in general run smaller in size than they do on the rocky reefs in the northern part of the lake. The eggs are of a much smaller size.

In Green Bay we have a lake trout which is strictly a bay trout; and is not found anywhere else on the shores of Wisconsin, either in Lake Superior or in Lake Michigan. They produce a red egg, like a wild brook trout, but of smaller size. We gather several millions in our fisheries operations in Green Bay, and they are usually planted in Green Bay. It has always seemed to me that the difference in color is largely due to differences of environment and to the kind of food eaten previous to spawning.

Dr. Davis: For two or three years we have matched individual pairs of fish and kept the offspring separate. We have not found any difference in the size of the eggs of fish from parents of the same size. We have conclusive evidence that there is considerable difference in the rate of growth of fish from different parents kept under as nearly the same conditions as possible as to space, number of fish and food. Certain fingerlings which were hatched last winter are fully twice the size of fingerlings from other pairs of fish, although kept under identically the same conditions. Unquestionably there is a marked difference in the rate of growth of fish from different parents, which persists for several years in succession in the same fish.

Dr. Emmeline Moore: Somewhere in the new index of the Transactions there will be found a reference to a discussion of the color of the flesh, as to whether or not it is of a genetic character. That discussion took place perhaps twenty years ago.

Dr. C. M. McCay (New York): Within the last few years there appeared a series of papers by Gray of Cambridge dealing with the size of fish produced from eggs under various conditions. He has shown that the size is affected by merely altering the temperature at which the eggs are held during the period of incubation. If he keeps his eggs very cold, and thus extends the period of incubation, in the end he gets larger fish; if he hatches rapidly he gets smaller fish. He correlates this result with the egg content consumed during this period and its later effect in restricting the development of the embryo.

President Culler: It would be interesting if fish culturists engaged in rearing lake trout would tell us something of the troubles they have experienced in regard to fertilizing the eggs. A great wastage occurs from the time the eggs are taken until they are "eyed" or reach the hatchery in the green stage. I think it was the intent of Mr. Hoöfnagle's paper to bring this point to the attention of the society in the hope that something might be done to remedy this condition.

Mr. T. Surber (Minnesota): In respect to the fertilization and non-fertilization of lake trout eggs, the first obstacle with which we have to contend along the north shore of Lake Superior is the weather conditions. Most eggs are taken at the season when storms are frequent. Many fisherman merely take the eggs in order to get a permit to take the fish, and do the work carelessly. For the past two years the Superintendent of the Lake Superior hatchery at French River has been carrying on a campaign among the north shore fisherman with a view to impressing them with the importance of properly fertilizing the eggs. I do not know the exact increase in the percentage of eyed eggs, but I imagine it is almost double that of four or five years ago. The most successful method of inducing the fishermen to take proper care of the eggs is individual instruction. We supply them with spawning pans and shipping cases so that they can make their own shipments. The eggs are shipped frequently by trucks so that they do not freeze. To stimulate the local production of better eggs we are planting the lake trout hatched from these eggs on the grounds from which the eggs came.

Mr. F. A. Westerman: In Michigan the eggs are taken almost entirely by the commercial fishermen and we co-operate with them only to the extent of saving the eggs. It would be a great improvement if these eggs were taken by state or government men, but it is practically impossible to supply a sufficient number of trained men at that season of the year.

We have made some computations as to the precentage of eggs saved. Millions of eggs are wasted even among those brought to the hatchery. In 1927, for instance, we saved only nineteen per cent of the potential take of lake trout eggs, as computed from the catch during the spawning season. In the case of whitefish we found that the percentage was only about eleven per cent of the potential yield of the catch during spawning season. The percentages in other states will compare closely with ours, because even under the regulations we now have, thousands of pounds of fish are taken just before the spawn is ripe for taking.

PRESIDENT CULLER: What would you suggest as a remedial measure?

MR. WESTERMAN: Still further control, possibly going so far as absolutely to forbid fishing during the spawning season.

MR. J. A. RODD (Canada): A few years ago we had a closed area at Colpoys Bay. The fish were retained on the spot where they were taken, throughout the ripening period under favorable conditions. In one particular year our hatch was over ninety-five per cent.

PRESIDENT CULLER: You mean that the wastage in the taking of eggs under the present method is due to carelessness or thoughtlessness on the part of the commercial fishermen?

MR. RODD: In a great many instances I do not think the commercial fishermen can help the wastage; it is due to the conditions under which they operate, particularly when they are using gillnets. But I do believe that great improvement can be effected in the quality of the eggs.

SOME FISHERIES PROBLEMS ON THE GREAT LAKES

By Dr. John Van Oosten

In Charge Great Lakes Fishery Investigations, U. S. Bureau of Fisheries

The extensive and intensive investigation of the Great Lakes fisheries by the United States Bureau of Fisheries now in progress was inaugurated July 1, 1927. The first step in this investigation was a brief preliminary survey by the writer of the conditions and problems that confront the American fishery industry on the various lakes. Fishermen were interviewed at all the important American ports on lakes Superior, Michigan, Huron and Erie.

In virtually every locality visited the fishermen expressed much concern in regard to the general depletion of the fisheries, the factors involved in it and the restrictive measures that have been proposed from time to time in various quarters. Many fishery problems were presented during this preliminary survey, the more universally discussed problems centering about the methods of fishing.

It is my purpose to outline briefly these problems of the commercial fisheries of the Great Lakes, to enumerate the various contentions relating thereto, and to present what scientific data we possess on certain controversial subjects—in short, to take an inventory of the stock of questions that confront the Great Lakes fishing industry today. By so doing we can obtain a better idea as to what should be done on the Great Lakes. Virtually all our recent research has been concentrated on Erie. The data collected on Erie since 1927 are too voluminous to discuss in the brief time at my disposal here and since a report on this work is now in progress for publication elsewhere, I would like to restrict the greater part of this paper to a discussion of the problems more or less common to lakes Superior, Michigan and Huron and to consider this introductory to the Lake Erie report. Lake Ontario was not visited and is not considered at this time.

Lakes Superior, Michigan and Huron

1. Hook Fishing. Hooks are employed primarily for lake trout on lakes Michigan and Superior and to a limited extent on Lake Huron. It is debatable at the present time whether these set lines are a detriment to the Great Lakes fisheries. Illinois prohibits hook fishing in its waters in Lake Michigan and the sentiment of the majority of the Lake Huron fishermen is against this method of fishing.

There are five objections to hook fishing commonly cited:

a. Hook fishermen destroy tremendous quantities of small fish (bloaters, chubs, herring) that serve as bait but that have a much greater potential commercial value as food for man or for the lake

trout. At times the bait nets (1½-2 inch mesh) destroy an undue amount of small fish taking far in excess of the number that are actually required for the hooks.

b. Dead bait thrown overboard by the hook fishermen contrary to law, fouls the spawning grounds especially those of the lake trout.

c. Hooks take large numbers of immature lake trout.

d. Hooks take the big and most valuable female spawners that cannot be taken in gillnets.

e. Hooks are floated at whatever level the trout swim while gillnets are fished on the bottom and therefore are less destructive to the trout population.

All of these criticisms are more or less justified, their validity varying with the lakes, the fishing grounds, and the character of the fishermen. The only data available on the character of the catch of bait nets are those published recently by Dr. Koelz. He examined eight lifts of 1½ in. mesh bait nets on Lake Michigan, seven on Lake Huron, and three on Lake Superior. All of these nets were presumably set by the hook fishermen for bait. Bait nets are set in water from 20 to 40 fathoms deep, most generally in about 30 fathoms. Koelz found no blackfins, whitefish or pilots in the bait nets examined and only one specimen of the chub (*johannae*). Likewise *kiyi*, a chub of no commercial value, occurred very rarely, being recorded once for Lake Huron and once for Lake Superior. The longjaw (*alpenae*) occurred as occasional specimens in two lifts only, the other lifts containing this species rarely or not at all, except the one recorded for Harbor Beach (Huron) lifted March 15, 1919, which comprised 21% longjaws. The subchub (*zenithicus*) was found in only two of the eight Michigan lifts and in five of the seven Huron lifts where it was recorded as "occasional" comprising, in one lift, 12% of the catch. (March 15, 1919. Harbor Beach, Michigan.) *Reighardi* comprised as high as 20% and 30% of the catch in the Michigan bait nets, but the bloater (*hoyi*) is the dominant form occurring in all the bait nets examined. Its percentage of abundance varied from 50% to 96% in Lake Michigan and the one record for Huron, where the bloater occurred abundantly, equaled 66%. The herring was sparsely represented in eight of the eighteen bait-net lifts. It is thus seen that four of the seven species of Great Lakes chubs are at times common in the 1½ in. bait nets. All of the species taken in the bait nets are commercially important, that is, reach a commercial size, except the kiyi and the bloater (*hoyi*) of lakes Superior and Huron (in Michigan and Ontario the bloater grows regularly large enough to be important) and virtually all would be immature or juvenile fish.

On the basis of Dr. Koelz's data on the bathymetric distribution of the coregonids we may expect to find the juveniles of at least five species of coregonids in the fishermen's bait-nets; longjaw, subchubs, reighard's chub, bloater and herring. Whether they are actually taken in abundance no one knows; we know only that in general large numbars of small coregonids are taken in bait-nets. The question concerning the quantities of juvenile chubs taken in these nets and at what seasons and under what conditions they are taken is in urgent need of further investigation.

2. Chub Nets. Chubs are taken in lakes Superior, Michigan and Huron in gillnets with stretched meshes that range from 2½ to 2¾ inches in length, although 2 3/8 in. nets are used illegally in certain ports. These small-mesh chub nets are known to take large quantities of small, immature lake trout in lakes Michigan and Superior but presumably not in Huron. The debatable questions which have arisen in this connection are:

a. Can chub nets be fished profitably out of all ports on lakes Michigan and Superior and at all seasons of the year without taking more than 10% of lake trout?

b. Can the number of immature lake trout taken in chub nets be reduced by decreasing or increasing the size of the gillnet mesh?

c. Which of the three meshes now employed in the various states is least destructive to immature lake trout—the 2½, 2⅝ or 2¾ inch?

d. Is the policy, now in force in Wisconsin, that all fish taken in legal gillnets be considered legal fish (legal mesh, legal fish) desirable and should it be adopted by other states or extended to include other type of gear?

The solution of these questions requires extensive experiments conducted simultaneously in various sections of the lakes and throughout at least one complete fishing season (one year). A few scattered and incomplete data relating to these questions are available at the present time and are shown in tables 1 to 3. The 1926 data for Alpena and Charlevoix (Table 1) were compiled from daily reports of the commercial lifts submitted by the fishermen to the Bureau of Fisheries. The table shows for each month the percentage by weight of lake trout taken in the chub nets of seven Alpena tugs and of three Charlevoix tugs. The numbers in parentheses represent the minimum and maximum percentages recorded for the month considered. Table 1 shows that on two occasions only did the percentage of the total catch of the month exceed the legal limit (10%), once in June at Alpena and once in September at Charlevoix although individual lifts contained as high

as 39.1% of lake trout. Contrary to what was expected the percentages for lake Michigan were no greater than those for Lake Huron.

The 1927 data (Table 2) were acquired, at the suggestion of the writer, by the Department of Conservation of the State of Michigan which detailed a number of game wardens to inspect the catch of chub nets as they were brought aboard the fishing tug. Table 2 shows the percentage by weight of lake trout in individual chub-net lifts for July, August and November (first row), the number of legal and illegal lake trout taken (second row—first figure refers to legal fish, the second figure following plus sign to illegal), and the depth in fathoms in which the nets were set (third row). It may be seen that, Whitefish Bay excepted, virtually all the percentages for Lake Superior exceed 10%, while those for Lake Michigan, Grand Haven excepted, range around the 10% limit. The Lake Michigan percentages for 1927 at Manistique (Table 2) exceed those for 1926 at Charlevoix (Table 1). The Hancock percentages for Lake Superior are consistently lower than the Grand Marais values for this lake although the depths fished were approximately the same in the two localities. The higher percentages of the latter port were not due to an unusually large number of lake trout but rather to the small catch of chubs, and fewer illegal trout were taken per lift at that locality (average = 29.3) than at Hancock (average = 58.2). Despite the comparatively low percentages for Manistique, the number of illegal trout taken per lift averaged relatively high (134.1). It appears then that the number of illegal trout destroyed must be taken into consideration as well as its percentage of abundance in the lift. The data of tables 1 and 2 indicate that chub nets can be fished at certain localities in lakes Huron, Michigan and Superior during July, August and November without destroying an undue number of immature lake trout.

Table 3 shows a summary by species of the number of fish taken in 2½ and 2¾ inch chub nets lifted November 5 and 10, 1928, out of Grand Haven, Michigan. These experimental nets were set under the direction of Mr. Wm. H. Loutit, Chairman of the Department of Conservation of Michigan. The table gives also the average length and weight of the various species and the percentage of each kind among the chubs. The table shows the following preliminary results:

1. The 2½ in. net took a slightly larger number of trout per net (5.5) than the 2¾ in. (5.0). Computations show, however, that the percentage of trout in the total number of fish is less for the 2½ in. net (5.2%) than for the 2¾ in. (8.1%) and also that the percentage of trout in the total weight is less for the 2½ in. net (9.7%) than for the 2¾ in. (21%).

2. The trout from the 2½" net averaged less in length (13.3" total length or 285 mm. standard length) and in weight (9.2 oz. or 262 gr.) than those from the 2¾" (13.7" total length or 299 mm. standard length; 12 oz. or 344 gr.).

3. Both nets drew upon the same species of fish, more than 90% of the chubs taken in each net belonging to two species, *hoyi* and *alpenae*.

4. The 2½" net took 33% more individuals of these two species (86 per net) than the 2¾" (58 per net).

5. The bloater, one of our smallest chubs, averaged slightly more in length and weight in the 2½" net than in the 2¾", while the longjaw averaged slightly less in length and weight in the 2½" net than in the 2¾".

The tentative conclusion, then, based on table 3, is that the 2¾" net is the better of the two kinds considered, for it takes fewer immature trout, it takes a larger trout and therefore draws upon a less abundant trout stock and hence is apt to cause less destruction among individuals and it draws upon the same species of chubs as the 2½" net does, but takes fewer individuals and consequently is less apt to deplete the rapidly dwindling species of chubs. It must be emphasized again that, as stated above, many more experiments need to be made to establish the validity of these conclusions. I present these data now because they are all we have on the hotly disputed subject at the present time.

3. Herring Regulations. My work on the herring of Saginaw Bay has shown that this species if not actually being depleted is certainly subjected to intense fishing. Old individuals are few; the fishery is supported by the younger age-groups, 78% to 85% of the commercial lifts being composed of III and IV-year fish. The percentage of older individuals (V-year group) in the commercial lifts decreased progressively during the years 1921-1924 while that of the younger (III-year group) increased. In fact so intense does commercial fishing appear to be in Saginaw Bay that a year-class is practically wiped out during its year of dominance in the fisheries. Briefly stated, the history of the majority of adult herring of a year-class seems to be as follows:

They are spawned in the fall, hatched in the spring, grow as immature fish for two or three years, attain sexual maturity in the third or fourth year, and are captured by the fishermen before or during their fifth year of life. Each year-class or brood predominates in the catch for one year only; it is rapidly depleted.

All available biological data show that the herring needs protection in Saginaw Bay. A closed season during spawning would tend to work a hardship on the industry for it is during this period mainly that

herring are available. A partially closed season may be feasible. Further, if the assumption that the majority of the fish must spawn once is valid, then, according to our data, a 10½" size limit (total length) must be established for these herring or expressed in weight 5½ ounces.

But how shall such a size limit for the herring be established in practice? It is not feasible to ask the fishermen to sort by hand the small, sensitive fish from tons of herring in November. The only alternative appears to be the sorting by mesh. But to increase the mesh without further investigation would be unwise. We must first ascertain what mesh, if any, is most effective in sorting the herring and then determine its effect on the gilling of herring and on the immature whitefish, yellows and other commercially important species. This work, begun in November, 1928, is now in progress on Saginaw Bay where in co-operation with the Department of Conservation of the State of Michigan and the fishermen, pound nets of 2", 2¼", 2½", 2¾" and 3" mesh are being fished on herring grounds. Final conclusions must await the completion of the experiment but the work so far suggests the following:

a. In the fall of 1928 no herring escaped through the larger meshes of the net for each size-group was represented in approximately the same proportion in the catch of the various nets (2", 2¼", 2½", and 2¾").

b. In the spring of 1929, however, some sorting seems to have taken place for the percentage of small herring in the lifts decreased progressively with each successive increase in the size of the mesh employed (2", 2½", 2¾", 3").

c. The number of herring that gilled before the fish were cornered increased progressively with each increase in the size of the mesh employed.

d. Virtually no immature whitefish or yellow pickerel gilled in the experimental nets.

Conclusions a and b are illustrated in table 4, which shows the percentage of herring under 261 mm. (10.2"), total length, taken in the various experimental pound nets set in Saginaw Bay. The percentages for the 2" nets of 1929 (inside and outside net) that fished side by side indicate that a variation of 5% in the percentages is not necessarily significant. The percentages of 1928 vary less than 8% with the nets, while those of 1929 vary from 10% to 20.5% and show a progressive decrease with each increase in the size of the mesh used. This interesting inconsistency in the apparent reaction of the herring in the fall of 1928 and in the spring of 1929 may possibly be explained on the following basis:

a. The percentages of the 2" mesh show that there were more small herring on the grounds in the spring of 1929 than in the fall

of 1928 and hence the effectiveness of the nets in sorting would appear to be greatest in 1929.

b. In 1928 the data were secured during the spawning season. It is very likely that due to sexual excitation the herring of 1928 were less aware of their surroundings and exerted less effort in escaping from their traps than those of 1929.

4. Chub Regulations. In his recent paper (1929) Dr. Koelz calls attention to the urgency of regulating and protecting the various species of chubs. The collapse of the cisco fishery on Lake Erie in 1925 induced the recent vigorous pursuit of the already depleted schools of chubs and "Drastic protective measures must be enacted if the chubs are not to be exterminated completely" (p. 348), says Dr. Koelz. It seems unfortunate that Dr. Koelz did not draw up the necessary protective measures for our guidance in regulating the chub fishery. The question of regulating the chub fishery involves many practical difficulties. Will the final answer be the establishment of refuges or in desperation the complete abolishment of the fishery for a period of years until the chubs have had an oportunity to come back?

5. Closed Seasons. The question of closed seasons is linked primarily with the question of the effectiveness of the hatchery in propagating commercial species of fish. Certain influential elements among the fishermen who never had faith in the hatcheries or who have lost it are striving for a strictly closed season permitting neither the governments nor the fishermen to collect spawn. The problems related thereto involve the unsettled and extremely difficult question of artificial propagation versus natural propagation. Other questions concern the variation in the spawning period of fish from year to year and with latitude or areas and the primary factors involved in this variation—temperature, race, etc. Upon the solution of this problem rests the feasibility of establishing zones for closed seasons during spawning according to latitudes. The question of closed seasons during the warmest months of the year to prevent undue destruction of juvenile fish or during the winter season to prevent lost nets from fishing under the ice indefinitely is generally a local problem that involves the fishing in shallow waters only—bays, reefs, etc., and can not be considered here.

6. Biological and limnological studies. There is urgent need for the scientific study of the biology of the commercially important species of fish and for a survey of the environmental conditions under which they live. We do not know as much about the Great Lakes fisheries as many fishermen believe we do. Our ignorance of the Great Lakes waters and its inhabitants is truly amazing. The representatives of the Russian government who in 1927 spent several days with me on

the Great Lakes expressed great astonishment that such a wealthy country as the United States has so long ignored a biological study of the most interesting chain of fresh-water lakes in the world. And in reality these visitors did not realize how superficial is our knowledge of the biology of these lakes! Except for some minor investigations made some 35 years ago and the recent survey now in progress on Lake Erie, no general limnological investigation has ever been made of any of the Great Lakes, while, contrary to the general belief, the life-histories of virtually all our commercial species of fish are unknown. We know virtually nothing concerning the age, growth-rate, and the age, length and weight at sexual maturity of the lake trout, the blackfin and the six other species of chubs, the pilots, the catfishes, the perch, the yellow and blue pike, the sauger, the sheepshead, the white bass, the sturgeon, the lawyer and the suckers or mullets of the Great Lakes. And it is repeatedly asserted that only on the basis of such knowledge can the fisheries be regulated intelligently! Here lies a big field for research as yet entirely unexplored by the scientist.

I suspect that the scientific investigators themselves are partly to blame for this state of affairs. In too many instances in the past have investigators used public funds for purely scientific questions, the solution of which no doubt extended our general knowledge in ichthyology but had no bearing on the practical problems of conservation—problems in which the general public were interested. Apparently an important psychological factor had been ignored for whereas the dictum in the field of finances is "No money, no interest", that in the field of conservation is the reverse, "No interest, no money". Fortunately, however, the trend of government fisheries investigations is, I believe, now in the right direction. The Bureau of Fisheries' main objectives in all its major investigations of the commercial fisheries may be stated broadly as follows:

a. The detection of the real trend in the abundance of the commercial species by the acquisition of adequate statistical and biological data.

b. The analysis of the factors that may influence the trend of the fishery.

c. The formulation of regulatory measures, if found necessary, with the view of restoring previous levels of abundance or of preventing a continuous decline in abundance.

It is to be noted that all three objectives aim directly at the preservation or conservation of the fisheries.

To ascertain the exact status of the fishery all the states on the Great Lakes have inaugurated recently, or have promised to do so, a new and uniform system of collecting statistical data. Heretofore, the

states required some kind of an annual report that was submitted at the end of the year. In many cases we know that these reports were incomplete and inaccurate. They attempted to furnish data on the number of persons engaged in the various branches of the industry and the kind, the amount and the value of investments and of production.

The new statistical blanks, however, which are submitted each month ask for a daily report on the number of pounds of each kind of fish taken, of the locality fished, of the kind and amount of fishing gear employed, of the length of time (number of nights) each unit of gear was fished without being lifted and of the kind and amount of spawn and caviar taken. These data interpreted in the light of the life-histories of the species will enable the biologist to express the catch in terms of fishing efforts and to make a critical and comparative study of the trend and conditions of each fishery in the various lakes and in the different areas of a lake.

The significance of accurate statistics is readily grasped by the practical fishermen, but the value of biological data is not always clear in their minds. They too often hold the impression, probably with some justification, that a scientist is a fantastical creation, an impractical idealist whose thoughts are generally somewhere in the seventh heaven (if there be such a place) far removed from the materialistic, mundane existence of the ordinary fishermen. Or, again, they may look upon the biologist as some supernatural being endowed with some secret, miraculous power to restore in a year or so the fisheries to their pristine condition—fisheries gradually depleted throughout the decades. In our present survey we are striving to disillusionize these fishermen. We are neither impractical, purely idealistic, nor supernatural but aim to reach a sympathetic understanding of the problems, the viewpoints, the ideas and ideals of the commercial fishermen. Our fisheries program on Lake Erie therefore has been planned as much as possible on a practical basis. We have attempted to ascertain from the fishermen themselves what questions they believed should be solved first and have followed their suggestions where possible irrespective of whether or not the work would interest the pure researcher.

I have thus far considered the major fisheries problems more or less common to lakes Superior, Michigan and Huron and have presented what little data are available to me on these major subjects. I believe that it has been apparent throughout that the data are meager indeed. Due to our extensive surveys we are much more fortunately situated with respect to the problems on Lake Erie. Although time does not permit a detail discussion here of the voluminous Erie data, I shall review hurriedly certain phases of our Erie program.

Lake Erie

Although Lake Erie is not typical of the Great Lakes, the following factors determined its selection as the starting point in our contemplated series of investigations on the Great Lakes:

1. From 1913 to 1925 Lake Erie produced on the average nearly 50% of the production of the Great Lakes.
2. The sudden slump in the important cisco fishery of Erie from 32 million pounds in 1924 to 5½ million pounds in 1925 and the persistence of this sudden decline created a demand for federal investigation on this lake.
3. Due to its relatively small area, its shallowness, its accessibility, and the extensive industrialization along its shores, Lake Erie offers the best possibilities to study the complex factors that affect the trend of the fisheres (overfishing, pollution, food, migration, storms, etc.).
4. On account of the diversity of the Erie fisheries it was believed that the results of the experiments on the fishing gear on this lake could be applied readily to the fisheries of other lakes.
5. The international situation is more acute on Erie than on any other lake due to the probable extensive intermigration of all the commercially important species of fish. In all probability, both Canadians and Americans are drawing upon the same stock of fish.
6. The question of uniform laws is most complicated on Erie due to the division of authority among five commonwealths.
7. The possibilities for co-operation were more numerous on Erie than elsewhere.

Various factors have been advanced in explanation of the collapse of the Erie fisheries. They are: 1, Destructiveness of fishing methods, 2, fishing intensity, 3, pollution, 4, increase in predaceous forms, 5, lack of food, 6, lack of proper closed seasons and areas and of proper size limits, and 7, natural fluctuations in the abundance of year-classes due to variations in environmental conditions at spawning or hatching time.

Our problem on Erie has been the evaluation of the various factors held responsible for the decline in the fisheries. The work was divided into two phases: a fisheries survey and limnological survey. The fisheries survey is conducted largely by the United States Bureau of Fisheries while the limnological investigation is a co-operative project carried on by the Game and Fisheries Department of Ontario, the Buffalo Society of Natural Sciences, the State of New York, the City of Buffalo, the State of Ohio and the Bureau of Fisheries.

In our fisheries survey we have accumulated extensive data on the destructiveness of the various types of fishing gear in various areas of

the lake and during various seasons of the year. In this work we accompanied the fishermen in their boats to the fishing grounds and obtained the percentage of illegal or small fish taken and destroyed by their nets. In the case of trapnets or poundnets, data were also secured on the extent of gilling of fish in the various sections of the crib or pot. In order to determine the effect of a change in mesh on the destructiveness of fishing gear we operated two series of experimental nets—shallow gillnets and trapnets. All the fish taken in these nets were brought ashore and studied and the experiments covered the seasonal variations in the fisheries.

Coincident with our work on fishing gear we collected data on the biology of the nine most important commercial species of fish. Such studies include data on age, growth, sexual maturity, longevity, mortality, spawning, migration, relative abundance of males and females, fluctuations in size-groups, in year-classes, in sex composition of schools, and in the relative abundance of the different species in the commercial lifts and on races.

Our Erie fisheries survey, then, has furnished us indisputable, scientific data on the comparative destructiveness of the various types of commercial gear now in use; it has supplied data on the effect of a change in the mesh on the fish population. From our biological studies we expect the following practical results: 1, The establishment of proper size limits and proper closed areas for each species, 2, the evaluation of the fluctuations in the natural supply due to natural causes as a factor in depletion, 3, the determination of the intensity of fishing, 4, the variation in the age and growth rate of the various species of commercial size, 5, the extent of migration between the states and between Canada and the United States, and 6, the determination of the existence of local races.

We have not ignored the fishermen in our survey. In addition to numerous personal interviews we submitted a questionnaire to some one hundred and fifty American and Canadian fishermen to obtain their views on the various problems under consideration. We have received splendid co-operation from the fishermen and by their frankness have received a fund of information based on practical experience.

The general limnological program "was designed with two objects in view: first, a determination of the natural requirements for successful production, such as the location of the spawning grounds, their relative importance as production centers, the food requirements of the fry, the abundance of this food, enemies, and migrations during the first years of their existence; second, careful tests to determine to what extent man has interfered with these natural requirements, to what degree the waters have been made impossible for fish life, what areas of the bottom

have been rendered unfit for spawning, etc." (Fish) In short to learn the physical, chemical and biological conditions that exist in the lake with particular reference to their bearing on young fish.

The limnological survey is now in progress but certain tentative conclusions based on the work of 1928 may be presented at this time.

1. Chemical and bacteriological tests and examination of bottom deposits for putrescent organic matter show that contamination of the waters due to trade and domestic wastes was restricted to local areas and in no case extended far from the source of pollution.

2. Determinations of dissolved oxygen, of free, fixed and half-bound carbon dioxide, of free and albuminoid ammonia, of nitrates and of hydrogenion concentrations show that, with the exception of the polluted areas, the chemical conditions of the lake are entirely satisfactory to the normal existence of organisms.

3. Plankton, the plants and animals that form the ultimate source of food for fishes, occurred in very great abundance.

In general, the results so far show nothing in the physical, chemical, and biological conditions of Lake Erie to explain the present depleted state of the commercial fisheries.

In conclusion, I wish to express the hope that our surveys will unite the dissenting factions among the fishermen and obtain concerted action towards the establishment of reasonable, practicable, enforcible and uniform fishery laws on Lake Erie and ultimately on the other Great Lakes also.

TABLE 1

MONTHLY PERCENTAGE BY WEIGHT OF LAKE TROUT TAKEN IN 2¾″ CHUB NETS FISHED OUT OF ALPENA AND CHARLEVOIX. THE VALUES IN PARENTHESIS REPRESENT THE MINIMUM AND MAXIMUM MONTHLY PERCENTAGES

Locality	May 1926	June 1926	July 1926	August 1926	September 1926	October 1926	November 1926
1. Alpena (Huron)	1.1 (0.0)-(3.0)	2.0 (0.0)-(3.1)	0.7 (0.0)-(1.5)	0.8 (0.2)-(2.8)			
2. Alpena* (Huron)	0.0	0.0	0.0	0.0			
3. Alpena (Huron)	5.0 (1.2)-(7.9)	5.1 (2.9)-(10.7)	3.7 (1.4)-(7.5)	1.6 (0.0)-(5.0)			
4. Alpena (Huron)	4.5 (2.7)-(7.7)	4.8 (0.7)-(12.4)	1.2 (0.2)-(2.0)	1.8 (0.0)-(7.1)			
5. Alpena (Huron)	1.6 (1.1)-(2.2)	0.2 (0.0)-(0.5)	0.4 (0.0)-(0.6)	0.6 (0.0)-(1.9)			
6. Alpena (Huron)	3.1 (0.7)-(33.3)	3.1 (0.3)-(13.4)	1.8 (0.0)-(7.9)	2.6 (0.0)-(4.1)			
7. Alpena (Huron)	8.6 (0.6)-(16.8)	17.5 (13.2)-(21.2)	9.7 (2.7)-(12.5)	1.0 (0.1)-(2.9)			
8. Charlevoix (Michigan)	......	......	......	3.8 (0.0)-(10.1)	17.1 (0.0)-(39.1)	2.1 (0.0)-(19.5)	
9. Charlevoix (Michigan)	0.6 (0.0)-(1.5)	1.4 (0.0)-(6.0)	2.8 (0.4)-(7.9)	2.3 (0.7)-(7.7)	1.9 (0.0)-(15.6)	0.8 (0.6)-(4.2)	6.7 (0.0)-(12.7)
10. Charlevoix (Michigan)	0.8 (0.0)-(3.7)	1.4 (0.0)-(5.6)	0.3 (0.0)-(1.0)	0.0			

*These nets were fished usually in water more than 60 fathoms deep and more than 45 miles from Alpena. Bearings were not given by other Alpena fishermen.

TABLE II

DAILY PERCENTAGE BY WEIGHT OF LAKE TROUT IN 2¾" CHUB NETS SET IN LAKES SUPERIOR AND MICHIGAN. NUMBER OF LEGAL AND ILLEGAL TROUT TAKEN AND THE DEPTH IN FATHOMS AT WHICH NETS FISHED

Locality		July 1927										
		13	15	16	18	19	20	21	22	23	24	25
Hancock (Superior)	Percentage				7.6	14.8	18.0	13.7	11.5	13.6		
	No. legal, illeg. trout				39+30	28+59	63+37	27+86	23+84	43+91		
	Depth in fathoms				35—68	32—55	82—90	34—58	38—68	35—55		
Grand Marais (Superior)	Percentage	31	36.6	25							26.5	20
	No. legal, illeg. trout	64+42	68+14	122+42							122+28	53+20
	Depth in fathoms	38—72	44—80	40—72							36—65	49—65
Whitefish Bay (Superior)	Percentage											
	No. illeg. trout											
	Depth in fathoms											
Manistique (Mich.)	Percentage											
	No. legal, illeg. trout											
	Depth in fathoms											
Manistique (Mich.)	Percentage											
	No. legal, illeg. trout											
	Depth in fathoms											
Grand Haven (Mich.)	Percentage											
	Depth in fathoms											

TABLE II (*continued*)

November

TABLE II (*continued*)

Locality		July 1927 26	28	29	30	August 1927 2	3	4	5	6	November 1928 5	10
Hancock (Superior)	Percentage	15.4										
	No. legal, illeg. trout	11+21										
	Depth in fathoms	38—68										
Grand Marais (Superior)	Percentage	19										
	No. legal, illeg. trout	92+30										
	Depth in fathoms	46—63										
Whitefish Bay (Superior)	Percentage		0.5	60		1.0	1.0	6.0	1.0	0.5		
	No. illeg. trout		3	616		7	8	60	3	2		
	Depth in fathoms		70—70	40—50		50—67	70—70	50—58	50—67	70—70		
Manistique (Mich.)	Percentage			10.0	10.0			9.0				
	No. legal, illeg. trout			4+232	2+36			4+148				
	Depth in fathoms			46—55	48—56			40—52				
Manistique (Mich.)	Percentage				10.0	16.0		8.0				
	No. legal, illeg. trout				2+90	4+238		61 ill.				
	Depth in fathoms				50	50		50				
Grand Haven (Mich.)	Percentage										12*	4.0
	Depth in fathoms										50	45

*Percentage by number; of 263 fish enumerated by me 231 were chubs and 32 were trout.

TABLE 3

SUMMARY BY SPECIES OF THE NUMBER FISH TAKEN IN 2½" AND 2¾" CHUB NETS LIFTED NOVEMBER 5 AND 10, 1928 OUT OF GRAND HAVEN, MICHIGAN, THE AVERAGE LENGTH AND WEIGHT AND THE PERCENTAGE OF VARIOUS SPECIES OF CHUBS*

Species	Lake trout		Bloater *L. hoyi*		Longjaw *L. alpenae*		Subchub *L. zenithicus*		Reighard's chub *L. reighardi*		Chub *L. johannae*		Kiyi *L. kiyi*		Lawyer	
Mesh	2½"	2¾"	2½"	2¾"	2½"	2¾"	2½"	2¾"	2½"	2¾"	2½"	2¾"	2½"	2¾"		
Total number	11	30	57	144	29	30	0	6	4	9	1	1	0	2	1	3
Average number per net	5.5 (2 nets)	5.0 (6)	57.0 (1)	48.3 (3)	29.0	9.7	0	2.0	4.0	3.0	1.0	0.33	0	0.66	1	1
Aver. total length in inches	13.3	13.7	8.7	8.4	11.2	11.5	.	11.3	11.1	10.8	11.6	11.7	.	8.9	13.9	13.2
Aver. stand. length in mm.	285 (10)	299 (23)	183	179	242	247	.	239	240	230	255	257	.	190	353	336
Aver. weight in grams	262	344	96	84	194	219	.	214	208	181	225	250	.	105		
Aver. weight in ounces	9.2	12.0 (17)	3.4	3.0	6.8	7.7	.	7.5	7.3	6.4	7.9	8.8	.	3.7		
% of each species of chubs			63.0	75.0	31.8	15.6	0.0	3.1	4.3	4.7	1.1	0.5	0.0	1.0		

*All the chubs were taken in one 2½" net and in three 2¾" nets, all lifted November 10, 1928, but the trout were from two 2½" nets and six 2¾" nets lifted November 5 and 10, 1928. All chubs were identified by Dr. Walter Koelz.

TABLE 4

SUMMARY OF PERCENTAGES OF HERRING UNDER 261 MM. (10.2"), TOTAL LENGTH, TAKEN IN VARIOUS EXPERIMENTAL POUNDNETS SET IN SAGINAW BAY

Year	2" mesh	2¼" mesh	2½" mesh	2¾" mesh	3" mesh
1928	29.8	34.3	31.8	26.8	...
1929	41.4 (inside net)	...	26.5	21.1	...
	36.6 (outside net)	...	...	...	...
	33.6 (3" control)	...	...	...	13.1

V.—Discussion

Dr. Van Oosten: I may add that I have presented these problems from the point of view of an American investigator. The Canadians, on the Great Lakes, may have different problems.

Mr. W. A. Cook: The nets used at Hancock, Grand Marais and Whitefish bay were all chub nets?

Dr. Van Oosten: Yes, all these percentages represent the percentage of trout taken in two and three-quarter inch chub nets.

Dr. M. J. Johnson: Dr. Van Oosten referred to possible lack of food and the activities of predacious fish. Did he find any evidence showing a change in the abundance of food or a change in the abundance of predacious fish corresponding to the time of depletion of the food fisheries?

Dr. Van Oosten: The factors which I enumerated were suggested by the fisherman or other interested persons. The increase or decrease of predacious forms refers particularly to the blue pike and the herring. Statistics show that an increase in the abundance of the blue pike is followed by a decrease in the herring, and when the blue pike decrease in abundance, the herring increase. The fishermen believe that the blue pike feeds principally on the herring. The fluctuations in blue pike and herring do not occur at the same time, so I do not know whether it is really a valid argument. One of the co-operative agencies is carrying on an investigation to determine whether the blue pike actually do feed on the herring. We have plenty of data on the food, collected by the limnological survey. The plankton forms of Lake Erie were studied in detail, and plankton is the principal food of the cisco in Lake Erie.

Dr. Johnson: Is there no indication that there has been a decrease in plankton in recent years to correspond with the decrease in cisco?

Dr. Van Oosten: We have no data on the basis of which we can make a comparison of the abundance of plankton as compared with that of previous years. The facts available now indicate that Lake Erie is very wealthy in plankton forms, but we know nothing about the plankton production of past years, except from the work of Professor Reighard.

Mr. J. Wicks: I was very much interested in what Dr. Van Oosten had to say with regard to the factor of pollution in the Great Lakes, and I hope that these studies will be prosecuted so that we may receive later more valuable information. Of course in the Great Lakes, as in the case of the sea, the factor of pollution is a very important one and the serious effects of pollution are not so apparent as in our inland waters. I have become very strongly convinced in recent years that in our inland waters the greatest enemy of fish life is pollution. A good deal is being done in the great cities along the Great Lakes to ameliorate the effects of pollution, notably in the case of Milwaukee, which by installing a sewage disposal plant has greatly improved the situation. The treatment of all sewage in Chicago is contemplated. At the present time it is diverted down the Illinois River. Cleveland, I believe, has a sewage disposal plant.

The North Sea fisheries might be mentioned in this connection. Sewage sludge from the city of London is dumped in the sea, and it is claimed by some that the great abundance of fish in the North Sea to some extent is due to this fertilizer.

I gather from the paper of Dr. Van Oosten that pollution in the Great Lakes as a factor in the maintenance and preservation of the fish life in those waters is a matter of only minor importance. Could he tell me about how seriously it is regarded and what is proposed in the way of further study.

Dr. Van Oosten: Until we reached the tentative conclusion as the result of our limnological survey it had always been supposed that pollution was a primary factor. Detroit, Cleveland, and Sandusky are located at the western end of Lake Erie, where the principal spawning grounds are found. There is pollution in Lake Erie, but it does not extend very far into the Lake. For instance, the waters of Dunkirk Harbour were very seriously polluted with absolutely no dissolved oxygen, but one mile out there is no sign of pollution. The storms in the shallow lake and the stirring up of the water apparently result in very rapid purification. You have to get quite near the source of pollution at Toledo in order to find serious traces. I am told that two years ago more whitefish were taken at Amherstburg at the mouth of the Detroit River than had been taken for years. In the first year of our work Mr. Wickliff took some very small whitefish in those, waters, and the only place he could find them was at the mouth of the Detroit River. This year he took some small whitefish at the mouth of the Detroit River, but more at Kelly's Island. Our results this year show that the pollution is locally restricted. The Great Lakes present a different proposition from the Mississippi River, where the pollution extends a good many miles down the river. From the information we have, I am convinced that the difficulty is not primarily pollution but rather over fishing.

Dr. Emmeline Moore: In this survey of Lake Erie chemical studies of pollution have been concentrated in the mouths of streams, where industry is centered. Our studies on the food of the fish in Lake Erie have not been without results, but we have still a long way to go before we can be sure that the local areas at the mouths of streams are not very important adjuncts of the lake fishery. In these weed areas are developed in large numbers the young which the predacious fish of Lake Erie feed upon. I am thinking of the Percina minnow, which is commonly found all through the small streams in the western part of New York State. The yellow pike fed very largely upon them. We found also that one of the great areas in minnow and small fish life was the Niagara River. We know how badly polluted it is, and we know also how wonderfully nature has provided an aerating system for the restoration of its waters. Although we have gained a great deal of information about the condition of Lake Erie, we still ought to be skeptical about the negative influence of pollution near the mouths of the streams, because these areas furnish an abundant supply of minnows.

President Culler: Is Dr. Van Oosten of the opinion that the discontinuance of the run of whitefish in the western end of Lake Erie around Stony Point is due to over fishing?

Dr. Van Oosten: I think the principal factor is an increase in the number of nets. During the spawning run, for instance, all the gillnet fishermen follow the schools and cut the fish off from their spawning ground. Those which escape the gillnets are received at the west end of Lake Erie by the trap nets, which have increased tremendously in number. At Kelly's, which is now the principal spawning ground of the whitefish in the west end of the lake, Mr. Wickliff could not even drag his tow nets because of the number of trap nets. There is scarcely a stone's throw between the strings, and I do not know how any fish can avoid them. Seven hundred nets are in operation now, and I do not know how many more will have been put in this year. The fishermen will tell you that the catch of whitefish is increasing. However, we find that formerly most of the eggs were taken by the Bureau of Fisheries hatchery west of the island, while the State hatchery covered the area east of the islands. The Federal hatchery supplied the whitefish eggs for both hatcheries. Now the reverse is true; the State hatchery supplies most of the whitefish eggs for the two hatcheries, as the fish do not go west of the islands. There is no evidence that the fish are increasing, but something has happened to prevent the fish from going west of the islands.

President Culler: Do you think it was due to the planting of the fish, which might cause them to run back to that particular area?

Dr. Van Oosten: Most of the eggs were taken west of the islands. If replanted on the grounds from which they were taken the fish were all put back west of the islands.

Dr. Emmeline Moore: What I said about pollution does not minimize the conclusions that have been drawn by Dr. Van Oosten. His statement is in

the nature of a demonstration of facts. I merely added by comment to indicate that from the standpoint of the chemist we do not yet know all the history of the adjuncts of the lake.

DR. C. M. MCCAY (New York): May I, as a chemist, voice some of the weaknesses of the chemist, and, without in any way offering criticism of this work, call your attention to the fact that the conclusions reached are the result of about two summers' work. It would take hundreds of chemists over a period of years to cover adequately such a huge body of water. Therefore the conclusions must tentative. In the next place, there is the lack of delicate chemical methods. When you say that an area of water is not polluted, you forget that the chemist today has only crude tools for measuring water pollution. We measure a few things in parts per million, but we are far behind in getting parts per billion, and it is parts per billion and parts per trillion that we must ultimately measure if we are to determine accurately the effects of chemical influences up on biological phenomena. Biological phenomena require far more sensitive chemical tools than any that are available today. We may say that a given area is unpolluted, that signs of pollution are absent, yet we are not certain because we have not the proper tools. So that we shall have to arrive at finer methods of making these measurements and devote long periods of study before we can say that a given area is unpolluted or that pollution is not affecting the life within that area.

DR. VAN OOSTEN: Can you measure oxygen in water?

DR. MCCAY: Yes.

DR. VAN OOSTEN: Oxygen is one of our most important criteria in pollution. Of course we have other criteria, such as the bacteria and the plankton. Of course you cannot analyze water for chemicals in a stream like the Detroit River, where there are any number of combinations that might take place among the chemicals in the water. But I consider that an abundant supply of plankton is pretty good evidence of lack of pollution. If oxygen determinations, bacteriological determinations, plankton studies, and the absence or presence of fish all consistently show you the same thing, I do not know why the results that we have reached so far are not absolutely reliable. I do not think the criticism of the chemical tests is going to alter our tentative conclusions, since they are justified even if we eliminated all the chemical work.

MR. HEUCHELE (Ohio): Only during the last four or five years have whitefish spawned below Kelly's Island. Do you think they were cut off by the fishing, before they had a chance to spawn?

DR. VAN OOSTEN: I found that the fisherman's increase in whitefish production was due to the shifting of the migration from the west to the east of the islands. Since we have found no trace of pollution on the former spawning grounds, I am unable to suggest a reason.

MR. HEUCHELE: This area appears just as good for spawning purposes today as it was twenty years ago, when practically all the spawning was done around Stony Point and Monroe.

DR. VAN OOSTEN: As far as we can learn from our limnological investigations, the conditions west of the islands on the former spawning grounds are just as good as the conditions on the spawning grounds around Kelly's Island.

MR. HEUCHELE: I wonder if the extending of the nets too far into the lake prevented the fish from working up along the Canadian or American shores to the spawning grounds.

DR. VAN OOSTEN: I do not know. There are strings extending a distance of seven miles from the short into Lake Erie which are continually in use, and I believe it is only fifteen miles across the lake at this point.

DR. W. J. K. HARKNESS (Toronto, Canada): I would like to ask Dr. Van Oosten if an analysis was made of the bottom organisms as a criterion of the amount of pollution?

DR. VAN OOSTEN: We have used the bottom flora as an indication of pollution.

DR. EMMELINE MOORE (New York): I think that more study should be given to the bottom organisms, since owing to financial limitations the work was only qualitative.

MR. J. WICKS (Minnesota): I am tremendously impressed with the remarks of Dr. Moore. I am not a scientist, but we all know that, starting with plankton one form of animal life furnishes food for a higher form, and so on up the scale until we get to the fish. Now, if by reason of a polluted condition at the mouths of streams flowing into the Great Lakes there is created a considerable area where the waters are not congenial to the smaller types of life, has there not been created a condition that might explain the absence of the larger types of fish life elsewhere in the lake?

MR. H. L. CANFIELD (Minnesota): At certain times the on-shore winds may affect the lake water in such a way as to give pure water at the mouths of the polluted rivers, such as the River Raisin. At such times it might be possible to find in those waters whitefish which ordinarily could not live there. Would not this condition have some bearing on the fact that you found small whitefish in polluted waters?

DR. VAN OOSTEN: The only whitefish which were obtained the first year were found at the mouth of the Detroit River, although seining operations were carried on all over that area.

MR. CANFIELD: I wish we could be a little more specific about the pollution areas and the extent to which pollution affected the fishes and other aquatic life. It seemed to me that you had given polluted waters just a little too clean a bill.

DR. D. L. BELDING (Mass.): May I call attention to the occurrence of irregular or transitory pollution? I have observed in the River Raisin, where ordinarily the pollution was insufficient to cause injury to adult fish, that with increased temperature of the water the amount of hydrogen sulphide gas, which is toxic for fish, increased beyond the ordinary level, with the result that no

fish could live in the river during the period of high temperature. In all pollution studies in the tributary streams of Lake Erie we must consider that at certain times under special conditions severe effects of pollution may be manifest that would not normally be apparent in an ordinary survey, unless the underlying dormant factors were recognized.

DR. WIEBE (Iowa): Possibly an examination of the condition of the bottom would show that the apparently sudden pollution was not so sudden after all. Two years ago I happened to be working on the Mississippi River at Hastings. Everything looked well on the surface and there was a good crop of algae, but the bottom showed a nasty condition. A few days afterwards I found that the force of the gas had dislodged the sludge deposits of the bottom so that they came to the surface, and the water was badly polluted.

DR. BELDING: If an examination had been made of the bottom of the River Raisin there would have been found conditions which, under favorable circumstances, would have caused badly polluted water.

PRESIDENT CULLER: One other phase of the depletion of the Great Lakes fisheries which might be discussed at this time is the subject of the proper planting of whitefish and lake trout. The fish are hatched in water at a depth of ten to twelve inches and are planted in water which has a depth up to one hundred and fifty feet. What effect will this sudden change have on the small fish?

MR. J. A. RODD: We have distributed sockeye salmon fry by sinking them in the lake to a depth of two hundred and fifty feet, with no apparent injurious results.

DR. EMMELINE MOORE: In the Finger Lakes district Dr. Eaton tried some experiments with fingerling lake trout, placing them in cages two hundred feet below the surface, evidently without any adverse effects. His experiments were continued through two different plantings, and he concluded that we had not been planting our lake trout fingerlings deep enough.

PRESIDENT CULLER: I had in mind an experiment in which lake trout fry in the yolk sac stage were lowered to a depth of one hundred and fifty feet in Lake Michigan. When they were brought back to the surface they were found to have burst open.

DR. EMMELINE MOORE: Planting fry to a depth of one hundred and fifty feet is a different proposition from planting fingerlings. The depth at which lake trout spawn would appear to be the optimum depth at which the fry would develop. It would be under one hundred and fifty feet.

MR. R. G. GALE (Minnesota): We have tried planting experiments only with lake trout fingerling, not with fry. During August last year we tested depths on twenty-five, fifty, seventy-five, one hundred, one hundred and fifty, one hundred and seventy-five and two hundred feet with negative results. The temperature ranged from sixty-four degrees F. at the surface to thirty-nine on the bottom. The fish were left in from two to five days. At two hundred and twenty-five feet, three bloated fish out of the twenty-five were found. At two hundred and

fifty feet a two-thirds loss was reported. It had taken eight minutes to lower from the surface.

I became convinced that we were killing our fish not from water pressure but from temperature shock. Therefore in lowering the fish we paused for five minutes at intervals of twenty-five feet. In raising the fish we made no pauses until we reached one hundred and fifty feet, when we paused every twenty-five feet.

President Culler: Is it not a fact that ninety-nine and nine-tenths per cent of the lake trout are planted in the fry stage, or just as soon as the sac is absorbed, and that the whitefish are planted in the sac stage?

Mr. Gale: Yes, from our hatchery.

INVESTIGATIONS IN POND-FISH CULTURE AT THE FAIRPORT BIOLOGICAL STATION

By H. S. Davis

U. S. Bureau of Fisheries

During recent years there has been a constantly increasing demand for the so-called warm-water game fishes, especially large and small-mouthed bass. Moreover, just as in the case of trout, it is becoming more and more apparent that under average conditions it is necessary to use fingerlings for stocking purposes if we are to get the best results. Doubtless there are some waters which can be stocked successfully with fry but it is probable that in most cases it will prove more satisfactory to use fingerlings for this purpose.

On the other hand many fish culturists have held that it is impracticable to rear bass to the fingerling stage on an economical basis and that to insure good bass fishing we must rely primarily on restrictive measures, supplemented to some extent by occasional plantings of fry. But if bass fingerlings can be produced in large numbers at a reasonable cost there would appear to be no reason why good fishing can not be maintained in suitable waters just as is being done so successfully with trout. In order to investigate the feasibility of producing bass fingerlings on a large scale the Bureau of Fisheries in 1926 started a series of experiments in pond-fish culture at its biological station on the Mississippi River at Fairport, Iowa. Over 20 ponds have been used in this work although several of them are so small as to be of little value for experimental purposes. In addition, a number of small concrete pools have been utilized for investigations on the effect of fertilizers on the production of plankton. During the first two years the largest pond used in this work was approximately one acre in extent. Later a larger pond with an area of 3.6 acres was added to those already in use. All of the ponds are supplied with water from the Mississippi River which is first pumped into a large reservoir and then distributed by gravity to the various ponds. Needless to say, only sufficient water is supplied to the ponds to replace that lost by seepage and evaporation.

While, as previously indicated, the experimental work has been devoted primarily to the propagation and rearing of large-mouthed bass other species of pond fishes have not been neglected entirely. Several ponds are used for propagating crappie and bluegill sunfish and in 1928 one pond was stocked with small-mouthed bass. Although much better results were obtained in this pond than were anticipated it is not our intention to devote much time to the small-mouthed bass until ponds are available that are better suited to this species than those at Fairport.

During the summer of 1928 we were able to extend our field of operations to the Upper Mississippi Wild Life and Fish Refuge. This has enabled us to increase materially the scope of our investigations. The work at Fairport is necessarily limited to artificial ponds but in the refuge we are dealing with natural ponds and sloughs where conditions are, in many respects, quite different. What success we may have in increasing the production of game fishes in these sloughs is for the future to determine but at least we believe that the effort is well worth while and we are optimistic enough to believe that we shall be able to increase materially the game fish population of the waters along the upper Mississippi and also have a surplus for stocking purposes elsewhere.

In our experiments at Fairport the primary object has been to produce fingerling fish as cheaply as possible with a minimum amount of labor. Consequently artificial feeding has been resorted to in only a few instances and in the case of the bass has been confined to capturing minnows for yearlings and older fish which are being held for brood stock. In rearing fingerlings our policy has been to make the ponds self-sustaining so that they will produce all the food required by the fish. Both our spawning and rearing ponds are stocked with adult minnows early in the spring to serve as brood fish, the only further additions to the ponds being small amounts of fertilizer at frequent intervals during the spring and early summer.

The spawning ponds are heavily stocked with brood bass and the advanced fry removed to rearing ponds. We believe this to be more logical than to attempt to remove the brood fish since there is less interference with the vegetation in the pond and we have complete control over the number of fry allowed in the rearing ponds. Of course the rearing ponds are fertilizd and stocked with forage fish some time before the bass fry are to be placed in the pond so that there is an abundant supply of food available for the young bass. Under these conditions we have found that a large percentage of the bass fingerlings survive until the ponds are drained in the fall when they will average from 2½ to 3 inches in length. In one instance the loss among the bass fingerlings during the summer was only 44% and our average loss is less than 60%. This comparatively small loss we believe to be due largely to the use of forage minnows. After reaching a length of one to one and one-half inches bass are primarily fish eaters and if there is an abundance of small minnows at hand they are much less liable to prey upon each other.

We are much encouraged over the fact that each year we have been able to increase both our average and our maximum production of bass fingerlings over the preceding year. In 1926 our average production of three-inch bass was at the rate of 4,400 per acre while the maximum

production was approximately 6,200 per acre. The following year the maximum production had risen to 8,500 per acre while the average production was about 5,300 fingerlings per acre. In 1928 we find that the maximum production was approximately 10,000 per acre with an average production of about 7,100 fingerlings. Of course these figures do not indicate an exceptionally large production of fingerling bass but it should be remembered that in all cases the ponds were self-sustaining, no food being added to the ponds aside from the fertilizer and brood minnows.

Our experiments have shown that better results can be obtained when the ponds are not overstocked and that if the brood fish are in good condition much smaller numbers are required than is usually realized. Overcrowding the fry has a tendency to increase cannibalism with the result that ordinarily less fingerlings survive the summer than is the case when smaller numbers are present at the beginning of the season. Consequently where the fry are to be reared in the same pond with the brood fish only a few pairs of adults are required to the acre. The fecundity of large brood bass is well illustrated by one of our spawning ponds which last spring was stocked with 17 large females and 7 males. Over 100,000 fry were transferred from this pond to rearing ponds. Since there were large numbers of fry still remaining in the pond it is safe to say that these bass averaged considerably over 6,000 fry to each female. Our records also show that in 1928 these same fish averaged at least 5,500 fry to each female.

One of our most difficult problems is the control of vegetation in the ponds. A too abundant growth of the higher plants is undesirable for several reasons not the least of which is the difficulty of removing the fish where there is an excessive amount of coarse vegetation. We have obtained our largest production in ponds containing only a moderate amount of the larger plants and it is evident that the fish are chiefly dependent on the smaller algae for their basic food supply rather than on the coarser vegetation. Of course the vegetation can be reduced by frequent cutting but this necessitates a considerable expenditure for labor. Plowing the ponds in the fall and allowing them to winter dry is a great help in reducing the amount of rooted vegetation but this is not always practicable. At present we are experimenting with sodium arsenite as a possible means of controlling the weeds without injury to the fish or materially interfering with the food supply. Preliminary experiments with this chemical have been very encouraging and if we can work out a successful method of controlling the vegetation by this means we shall feel that one of our greatest problems has been solved.

We have found it advisable to rear our own brood bass and additions to our brood stock are limited strictly to fish which have been reared

in our own ponds. Each year a few of our very best fingerlings are reserved for brood stock and we believe that in this way we shall get better results than if we depend on wild fish for this purpose. No difficulty has been experienced in rearing these fish and during the past season fry were obtained from both three-year old and two-year old fish which had been reared in the Fairport ponds. We also have conclusive evidence that large-mouthed bass may spawn when only one year old but it is probable that this is exceptional rather than the rule.

In conclusion I should like to emphasize the fact that I believe that the time is fast approaching when the rearing of our own brood stock will be just as essential a part of pond-fish culture as it is today of trout culture. Wild fish are becoming more difficult to obtain each year and only by rearing our own stock can we be assured of a constant supply of brood fish. Furthermore, this is more in harmony with the ideals of true fish culture. The antiquated practice of capturing large adult bass and transferring them long distances to a hatchery—more often than not with heavy losses—is of doubtful efficiency. I strongly suspect that in most instances those fish would have produced more young had they been left to spawn in their native habitat.

Even in our work on the sloughs of the UpperMississippi Wild Life and Fish Refuge we have come to the conclusion that we must rear our own brood stock. Dependence on wild fish for stocking the sloughs is altogether too precarious and, furthermore, it savors too much of the not uncommon practice of "robbing Peter to pay Paul."

VII.—Discussion

Mr. D. H. Thompson (Illinois): Is coarse aquatic vegetation recommended at all in bass ponds?

Dr. Davis: I do not feel in a position to give a definite answer but I know that we have obtained good results from ponds in which there was no coarse vegetation.

Mr. D. H. Thompson: In connection with a survey of the Illinois Conservation Department's hatcheries this summer we found that a moderate amount of vegetation appeared more favorable than none at all, and that excessive amounts, particularly if clogged with algae, are worse than none.

Mr. E. L. Lecompte (Maryland): May I ask whether the brood stock were removed from the ponds in which these fingerlings were held?

Dr. Davis: Our practice is just the opposite, we remove the fry and leave the brood fish in the ponds.

Mr. Byers (Montreal, Canada): Will Dr. Davis state the name of the particular minnow that was used for forage?

DR. DAVIS: We are using chiefly two minnows: the blackhead minnow and the golden shiner. Comparative tests between the two species show that the golden shiner is preferable for bass ponds. The chief advantage of the golden shiner is found in its larger size, particularly since fingerling bass grow rapidly and by the middle of the season have reached a relatively large size. When the small blackhead minnow is used there are almost none left at the end of the season, whereas the golden shiner continues spawning until the middle of the summer, and furnishes a continuous supply of young minnows.

DR. EMMELINE MOORE (New York): Perhaps the blackhead is a little more delectable.

DR. DAVIS: We are trying this year a combination of the two species. No artificial food is used except a fertilizer consisting of superphosphate, acid phosphate and dried sheep meal.

MR. GILL (Iowa): How many male and female fish did you have per acre of water?

DR. DAVIS: Too many factors enter into that problem to enable me to give an offhand answer. We are now stocking our nursery ponds with fry at the rate of 25,000 to the acre, based on an expected survival of at least forty per cent, which would give us about 10,000 three-inch bass in the fall. If you are using bass in the ponds from which you expect to remove a large proportion of fry, you would naturally use larger numbers. If you have brood fish that you can depend upon for five or six thousand fry to the pair, you need only five or six pairs to the acre.

DR. A. H. WIEBE (Iowa): We have been using six to seven hundred golden shiners to the acre.

MR. I. T. QUINN (Alabama): Does Dr. Davis find that the older brood bass are more cannibalistic than the younger stock?

DR. DAVIS: No. The large fingerlings and the yearlings are the principal offenders in the matter of cannibalism.

MR. QUINN: I refer to whether the younger brood stock are more or less cannibalistic than the older and larger bass?

DR. DAVIS: We have no data on that point.

MR. QUINN: Do you find that the old basses do not spawn as regularly as the younger brood stock?

DR. DAVIS: All our old bass have done very well; for instance, we obtained over 100,000 fry from seven males and seventeen female bass, four to five years old, held in a three-quarter acre pond.

MR. QUINN: We have in our hatchery in Alabama some bass that will weigh around six pounds. Would you recommend that this size be held as brood stock?

DR. DAVIS: Ours are not as large.

Mr. Quinn: Do you find that your wild stock the first year it is introduced into your breeding ponds spawn as naturally and as well as the stock which has been reared in the ponds?

Dr. Davis: I do not think they do, but I have little data upon which to base an opinion.

Mr. H. L. Canfield: Dr. Davis referred to some bass spawning at one, others at two years old. I wonder whether he knows the reason.

Dr. Davis: Each year our largest fingerlings are selected for brood stock. The spawning of the yearlings was entirely unexpected. We have no knowledge as to how many spawned. All we know is that we found fingerlings in the fall which were undoubtedly the young of the yearlings.

Mr. Canfield: Then you could not say it is due to size alone?

Dr. Davis: The large trout spawn earlier than the small ones, and I suppose the same is true of bass.

Mr. Quinn: Has Dr. Davis any data on the comparative value of concrete and earthen pools in the propagation of bass?

Dr. Davis: All our pools are dirt pools. I do not believe in concrete pools for fish.

Mr. G. Berg (Indiana): Has the chub sucker ever been used as a forage fish for bass?

Dr. Davis: Not to my knowledge.

Mr. Berg: At one of our Indiana stations this year, in a pond of about two acres we had a production of 40,000 No. 1, 2 and No. 3 fingerling large mouthed bass. In this pond there were a large number of chub suckers, which were accidentally introduced. I believe the presence of the chub suckers was largely responsible for the excellent output from that pond.

Mr. P. Viosca (Louisiana): I would like to report on a little experiment conducted at one of our stations in Louisiana, which may be of interest in connection with the spawning of one year old bass. We put in a one acre pond one hundred large-mouthed bass fry, one hundred blue-gill fry, and one hundred warmouth fry. No artificial food was provided. The following spring, in the month of March, the bass, which were one year old, began nesting and quite a number of the nests were laid, although sudden cold weather destroyed the eggs. The bluegills and warmouths also spawned. After a year and a half we drained the ponds and took out one hundred large bluegills, one hundred large warmouths, and eighty-nine large-mouthed bass. Two large-mouthed bass had been taken out previously for the purposes of recording measurements, so that left a mortality of nine among the three hundred fish.

Mr. J. Wicks (Minnesota): A voluntary effort in bass culture which was made in the vicinity of Minneapolis, about ten miles from here, by our local chapter of the Izaak Walton League may be of interest. Three years ago we

secured a lease on a twenty acre tract of land that had been a meadow for forty years. By damming a spring fed stream, which flowed about one hundred yards, we covered the meadow with a pond of shallow water, which produced a tremendous mass of green algae. Late in the spring we planted 134 brood bass of unknown sex. About the first of July the fish began to spawn and about the last week of September we took, by actual count, something over 51,000 bass, averaging between five and six inches in length.

Last year we induced the State Game Commission to take over the operation of our pond. Last year they took out some 78,000, if I remember rightly, and this year it is our expectation to take out around 100,000. Stimulated by this example some eight or ten other similar bass ponds have been started in the State of Minnesota. It seems to me it ought to be the policy of both the Federal and State governments to encourage such voluntary efforts.

MR. CANFIELD: The members of the Minneapolis Chapter of the Izaak Walton League, who carried the burden of this venture, deserve our most hearty appreciation. These gentlemen, with no particular knowledge of fish culture, but simply fish enthusiasts, secured the grounds, put out their money, and produced these fish on a minimum of information furnished by the Bureau and the State Fisheries Departments. But these gentlemen kept accurate account of the expenses, the number of fish introduced, and actually counted each fish taken from the pond. They gave to Hennepin county the biggest planting of bass ever received from any fisheries organization. I have been with the Bureau of Fisheries since 1900, and I never heard of distributing a solid carload of bass in any one county.

MR. J. A. RODD (Canada): Can anyone here give us definite information regarding the value of fresh water smelt as a forage fish, particularly for bass?

DR. EMMELINE MOORE: Our studies on the smelt on Lake Champlain this year indicate that this species is used largely by the pike perch. Data upon bass will be forthcoming sometime in the spring when all the available information has been compiled in the study of the smelt as a forage fish.

DR. METZELAAR (Michigan): In 1928 we secured some eggs from the only smelt lake in Michigan. After hatching the young smelts, 6.5 mm. in length, were transferred to the bass ponds, which contained small yellow perch. None ever survived.

DR. EMMELINE MOORE: We have found that the yellow perch eat smelt.

MR. E. L. LECOMPTE (Maryland): Were the bass fed anything other than the natural food in the twenty acre pond described by Mr. Wicks?

MR. WICKS: Minnows were placed in the pond as food for the mature bass.

MR. T. SURBER (Minnesota): It has not been necessary to introduce food for the young fish, because this pond is literally alive with entomostraca and aquatic insect larvae. As soon as we can get rid of the meadow that composes the bottom we have no doubt that we shall be able to rear a quarter of a million fingerling fish.

MR. WICKS: In this connection may I inquire as to the possibility of drawing down insect food by means of lights? If that could be done it would be an important factor in the breeding of the fish.

PRESIDENT CULLER: The old-time gasoline lamp has been used for that purpose in a number of places. In Texas a string of electric lights is located over the pond, down close to the surface of the water.

MR. VIOSCA: We find that the use of electric lights over the water is very efficient.

THE EFFECTS OF VARIOUS FERTILIZERS ON PLANKTON PRODUCTION

By A. H. Wiebe

With the assistance of Rowena Radcliffe and Fern Ward

U. S. Bureau of Fisheries

Introduction

The immediate object of the experiments reported on in this paper was to determine if plankton production would be increased through the addition of fertilizers and also to determine if different kinds of fertilizers would differ in their effectiveness. The ultimate object is, of course, to increase fish production.

When we fertilize a pond, especially when organic fertilizers are used, we are in reality polluting the water of the pond. We may, therefore, be considered guilty of deliberately opposing those who are fighting pollution in an effort to keep our waters clean and a suitable environment for fish. The situation is, however, not quite as bad as may appear at first sight: we are not adding enough fertilizers to endanger the life of fish or of other organisms that may be present in the water and that may serve as a source of fish food. In our practice the addition of various fertilizers is so regulated as to prevent any serious depletion of the dissolved oxygen and also to prevent the accumulation in harmful concentrations of toxic substance that may arise during the decomposition of organic fertilizers like soybean meal and shrimp bran.

Some Limiting Factors

Our object in adding fertilizers to the ponds has been mainly to keep available a supply of inorganic nitrogen and of soluble phosphorus. On the basis of the work that has been done by Brandt, Garrder, Grau, Atkins, Harvey, and others on the waters of the North Sea, of the English Channel, and of the Atlantic Ocean, Harvey (1926) concludes, "there is an excess supply of the requirements for photosynthesis with the exception of phosphates and nitrates" and, "the fertility of an ocean will depend for the most part on two factors, namely, the length of time taken by the corpses of marine organisms and excreta to decay, and the length of time taken by the phosphate and nitrate so formed to come again within the range of algal growth".

In the course of my investigations at the Fairport, (Iowa) station many determinations of nitrogen have been made. (Organic nitrogen; and nitrogen as nitrates, as ammonia, and as nitrites were determined). Numerous determinations of soluble and of total phosphorus have

likewise been carried out. These tests, now covering three seasons, have shown that nitrogen in the forms of nitrates and of ammonia was present at all times. As these are the two forms of nitrogen ordinarily utilized by algae and other plants, it may be assumed, that nitrogen was not a limiting factor. The results with respect to the soluble phosphorus are quite different. On numerous occasions the writer has found that no dissolved phosphorus was present. Hence the soluble phosphorus may be considered a limiting factor. (Phosphorus is a constituent of most forms of protoplasm).

Another factor that may limit the production in a pond at times is carbon dioxide. The algae use not only the free CO2 dissolved in the water, but are also known to utilize some of the CO2 of the bicarbonates of calcium and of magnesium [Ca (HCO3) 2 and Mg (HCO3) 2]. The algae, however, cannot use the CO2 of the normal carbonate (Ca CO 3 and Mg Co3). In a series of tests made to determine the magnitude of the changes in the dissolved oxygen and the alkalinity that may occur during the 24-hour period, I have found several instances where the phenolphthalein alkalinity was greater than one-half the methyl orange alkalinity. This according to "Standard Methods of Water Analysis" would mean that the alkalinity was due entirely to the presence of the normal carbonate and the hydroxide. From the standpoint of productivity it would mean that the algae had used up all the available CO2. This would mean that CO2 was a limiting factor. Practically this is not of very great importance in our ponds: it occurs only when the production of algae is on a very high level, i.e. when a condition of water bloom exists.

Description of Ponds

The ponds used in this experiment were a series of six small cement ponds. These ponds are 50 feet long and 8 feet wide, and each pond has an area of 378 sq. ft. The ends are in the form of a semi-hexagon which accounts for the reduced area. The depth of the water in these ponds was 14 in. at the upper end and 20 in. at the lower end. This would give each pond a volume of water of approximately 530 cu. ft.

Treatment of Ponds

The following fertilizers were used in these experiments: superphosphate, soybean meal, shrimp bran, and sheep manure. During the time of these experiments which covered the period from June 7th, 1928, to Sept. 20th, 1928, C-1 received 3 lbs. of superphosphate, C-2, 11 lbs. of soybean meal, C-3, 11 lbs. of shrimp bran, and C-6, 11 lbs. of sheep manure. C-4 was used as a control without fertilizer. In addition to the soybean meal C-2 received 5 oz. of superphosphate. An analysis of the soybean meal gave the following results: total phos-

phorus 1.2%, nitrogen (exclusive of nitrate nitrogen), 24%, and total organic matter 60.9%. A similar analysis of the shrimp bran yielded these figures: total phosphorus 1.9%, total nitrogen (exclusive of nitrate nitrogen), 7.1%, and total organic matter 52.6%. The super phosphate is the 16% acid phosphate of commerce.

Results

In table 1 there is given a brief summary of the relative abundance of the principal algae in C-1, C-2, C-3 and C-4. The algae in the plankton from C-6 have not yet been enumerated. The table shows that on the whole there is a large increase in the number of algae in the fertilized ponds. These results agree with those of Jaernefelt (25). (A more complete discussion of the plankton algae is given in another paper now in course of publication elsewhere. This paper also gives a complete discussion of the chemical data collected during the course of these experiments).

TABLE ONE

This table shows the relative abundance in the different ponds of the C-series of the principal algae in centrifuge plankton. 1928.

Pond	Organism	Date 6/27	7/7	7/19	7/28	7/30	8/9	8/20	8/30
C1	Scenedesmus	855		4,500			7,200	1,843,200	7,680,000
C2		8,550,000	546,840	180,000			39,060	2,430,400	720,000
C3		3,840,000	780,000	1,260,000		149,730	63,000	337,500	3,176,880
C4			3,000	123,000		12,000	3,000	63,000	78,000
C1	Chroococcus single cells		9,000						1,800,000
C2		1,140,000	2,994,600	342,000		48,000	1,178,310	13,888,300	8,032,000
C3		17,920,000	528,000	4,230,000		2,252,460	126,000	126,000	1,236,900
C4		13,500	6,000	126,000		9,000	30,000	66,000	210,000
C1	Chroococcus colony			22,500					
C2			195,300	54,000			572,880	3,333,120	9,728,000
C3						234,360		9,000	429,660
C4									
C1	Aphanizomenon	14,400		9,000					
C2		205,500,000	11,160,000	58,320,000		40,200,000			
C3		48,000,000	252,000	101,700,000		868,050	693,000	1,368,000	
C4			24,000	264,000				6,000	
C1	Oocystis single cells			31,500	36,000	21,600	93,600	563,200	1,920,000
C2		240,000	442,680	90,000		18,800	91,140	729,120	720,000
C3		48,000	72,000			91,140	36,001	126,000	1,219,720
C4			3,000	24,000		3,000	12,000	9,000	24,000
C1	Oocystis colony	840,000						960,000	
C2		840,000							
C3									234,360
C4				12,000				3,000	9,000
C1	Pleodorina				960,000	115,200	216,000		
C2									
C3									
C4									
C1	Pandorina			4,500	24,000	756,000	748,800		
C2									
C3									
C4									
C1	Synedra	14,400						6,400	
C2		540,000	450,000	540,000					48,000
C3		7,040,000						18,000	
C4				3,000					

Note: On July 28th no samples were taken from C2, C3, and C4.

Table 2 gives the average number of all crustacea, exclusive of the nauplii, per litre. These are the averages in each case for from 68-70 samples. This table shows that in each case the fertilized ponds produced more crustacea than the control.

TABLE 2

Pond	C-1	C-2	C-3	C-4	C-6
No. of crustacea	484.4	1957.0	621.4	265.7	660.4

In table 3 are shown the average number of all rotifers per litre of water. The table shows that the rotifers were most abundant in C-1, i.e. in the pond that was fertilized with superphosphate. The second largest number of rotifers occurred in the control pond, C-4. The rotifers seem to prefer clean water. These results as far as the rotifer *Anurea* is concerned were contrary to the views that are now held by some biologists, namely, that this genus thrives best in waters that are somewhat polluted.

TABLE 3

Average number of all rotifers per litre of water.

Pond	C-1	C-2	C-3	C-4	C-6
No. of rotifers	1826.4	152.4	219.5	686.6	117.15

Table 4 gives a summary of the animals of the plankton from each pond according to genera. There are given for each genus: the number of samples for each pond, the average number per litre, the maximum number per litre and the date on which this maximum number occurred. As this table is self-explanatory, it is unnecessary to discuss its contents in detail here.

TABLE 4.

Showing for each genus the number of samples, average number per litre, maximum number per litre, and the date on which maximum occurred.

Organism	Pond	No. Samples	Average per litre	Max.	Date when max. occurred
Cyclops	C-1	68	70.38	572	6/23
	C-2	69	650.07	1737	6/19
	C-3	70	503.73	4383	6/22
	C-4	68	31.53	388	8/1
	C-6	70	186.18	2395	6/24
Diaptomus	C-1	(None present)			
	C-2	69	.05	2.1	8/29
	C-3	70	.04	1.5	9/16
	C-4	68	1.4	2.7	9/15
	C-6	70	3.9	20.5	7/30
Bosmina	C-1	68	325.19	1287.75	9/17
	C-2	69	1216.39	6854.25	8/27
	C-3	70	26.36	123	7/12
	C-4	68	208.12	2691	6/28
	C-6	70	432.75	1749	8/3
Moina	C-1	68	4.89	172	8/17
	C-2	69	80.27	409	8/28
	C-3	70	52.3	477	8/29
	C-4	68	7.07	176.5	8/1
	C-6	70	6.66	57	7/6
Daphnia	C-1	68	4.53	54	6/30
	C-2	69	3.65	66	9/20
	C-3	70	37.94	428	8/31
	C-4	68	1.3	15.75	6/30
	C-6	70	7.2	69.3	6/30
Ceriodaphnia	C-1	68	69.61	438	8/4
	C-2	69	5.9	241.5	8/31
	C-3	70	.76	19.5	8/20
	C-4	68	13.6	112	9/1
	C-6	70	9.52	155.25	9/19
Diaphanosoma	C-1	68	8.06	60	8/6
	C-2	69	.54	9	6/20
	C-3	70	.15	3	7/13
	C-4	68	2.01	15.5	8/23
	C-6	70	12.59	116	8/20
Alonella	C-1	68	.38	7.5	8/18
	C-2	69	.06	3	8/31
	C-3				
	C-4	68	.17	2	7/28
	C-6	70	.39	2.5	7/30
Scapholeberis	C-1	68	1.19	18	8/16
	C-2	69	.04	2	9/19
	C-3	70	.01	1	8/15
	C-4	68	.14	1	8/11
	C-6	70	.81	17.25	8/24

TABLE 4 (*continued*)

Organism	Pond	No. Samples	Average per litre	Max.	Date when max. occurred
Chydorus	C-1	68	.11	3	9/6
	C-2	69	.04	1.5	6/20
	C-3	70	.02	1	9/19
	C-4	68	.04	.75	9/19
	C-6	70	.18	2.25	8/16
Ostracod	C-1	68	1.19	18	6/16
	C-2	69	.03	2	8/16
	C-3	70	.09	4	9/19
	C-4	68	.34	2.25	9/19
	C-6	70	.28	6.4	8/23
Nauplius	C-1	68	3649.68	48000	8/2
	C-2	69	511.16	2139	6/19
	C-3	70	493.98	3138	7/14
	C-4	68	622.95	5000	8/1
	C-6	70	251.5	1060	7/19
Anuraea .... cochlearis	C-1	68	628.74	9000	8/2
	C-2	69	70.79	1386	6/15
	C-3	70	84.98	1770	6/16
	C-4	68	199.62	3300	6/13
	C-6	70	71.63	502	6/13
Anuraea aculeata	C-1	....	....	....	....
	C-2	....	....	....	....
	C-3	70	.14	10	8/18
	C-4	68	1.5	100	6/13
	C-6	70	.04	3	7/19
Anuraea sp?	C-1	68	62.43	1000	6/13
	C-2	69	21.67	452	6/15
	C-3	70	45.06	1293	6/15
	C-4	68	76.32	1000	6/23
	C-6	70	18.78	407	6/13
Polyarthra	C-1	68	845.24	15000	8/1
	C-2	69	46.92	546	6/19
	C-3	70	46.66	441.6	6/16
	C-4	68	344.19	4770	7/19
	C-6	70	21.05	187	6/30
Triarthra	C-1	68	59.85	2100	7/31
	C-2	69	2.76	118	6/7
	C-3	70	16.45	710.4	6/16
	C-4	68	14.4	400	6/16
	C-6	70	2.08	84.5	6/7
Brachionus	C-1	68	3.53	150	6/25
	C-2	69	8.9	364	6/15
	C-3	70	26.13	902.4	6/7
	C-4	68	24.34	500	6/16
	C-6	70	.53	20	6/23
Monostyla	C-1	68	194.12	3000	8/2
	C-2	69	.09	6	6/28
	C-3	70	.04	3	7/18
	C-4	68	.18	6	8/15
	C-6	70	.55	16	7/23

TABLE 4 (*continued*)

Organism	Pond	No. Samples	Average per litre	Max.	Date when max. occurred
Cathyna	C-1	68	32.55	500	5/10
	C-2	69	.53	9	8/15
	C-3	70	.04	3	7/14
	C-4	68	24.41	400	7/18
	C-6	70	2.49	35	7/19

Summary

The results of the experiments discussed in this paper point toward the conclusion that the plankton production may be increased through the use of various fertilizers.

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VIII.—Discussion

Dr. Wiebe: This report refers to work which has been in progress for three of four years. Since the completed report is not ready at this time, I am submitting merely a preliminary statement.

By fertilizing a fish pond we aim to increase fish production. In fertilizing we deliberately pollute the waters in which we expect the fish to live. In that respect we may be said to be proceeding at variance with the principle of keeping a clean environment for the maintenance and preservation of fish. In this connection I wish to give you a few facts which may be appropriate following the outline presented this afternoon by Dr. Davis, who is in charge of the work.

In this experiment we have used superphospate and sheep's manure, singly and in combination. We have tried soy beans and, on a small scale, shrimp bran, which is ground up shrimp refuse. So far we are interested primarily in the nitrogen and phosphorus they supply. Those who are familiar with the work on the Atlantic coast, as well as in the Plymouth Laboratories and some of the Scandinavian countries, will recall that they have concentrated largely

on the phosphorus and nitrogen in the sea water. Harvey has recently made the statement that the productivity of the ocean will depend upon the available nitrates and phosphates—that is, the inorganic soluble nitrogen and inorganic soluble phosphorus. Other forms of nitrogen, *e.g.* atmospheric nitrogen, would not be readily available unless it was fixed by nitrogen-fixing bacteria. So they read the abrupt conclusion that productivity will be limited by the amount of available nitrates and phosphates, and after they are exhausted of course it will depend on the time required for those organisms in which they are bound up to disintegrate and again be reoxidized to phospates and nitrates.

We have run nitrogen determinations not only of the organic nitrogen, which would not be immediately available, but also of ammonia nitrogen, which can be used and is extensively utilized by some of the bluegreen algae, according to plant physiologists; and of the nitrates and the nitrites. We are interested primarily in the nitrites, because they give us information as to whether or not we are overpolluting our ponds. Large quantities of nitrite nitrogen would not be so advantageous, because nitrite nitrogen possesses an oxygen demand.

In the determinations we have carried on during the last two years we have never found that either ammonia or nitrate nitrogen, although low at times, was completely absent. Of course we do not know how much of these substances would be required to give an optimum condition, but at least we know that so far as our ponds are concerned, which of course is a limited environment, the nitrogen is not exhausted. We have found that the phosphorus is present at times, or even absent altogether, as far as chemical tests capable of detecting at least one one-thousandth part per million are concerned. So we aim particularly to supply these two things through the various fertilizers.

During the past summer we have tried to get at the magnitude of the changes that may take place say within twenty-four hours. At one time of day we find a certain situation with regard to the oxygen or the free carbon dioxide or the haif-bound or bound carbon dioxide, whereas if we had taken samples at other hours the picture may have been entirely different. From a study of changes over a twenty-four hour period, especially in regard to the dissolved oxygen, carbon dioxide and free ammonia, we have found that there exists in a pond, when photosynthesis is going on rapidly, an hydroxide alkalinity. When an hydroxide alkalinity exists it means that the algae have consumed not only all the free carbon dioxide in the water but also what is commonly referred to as the half-bound carbon dioxide and, according to some authorities, all the bicarbonate carbon dioxide. If the assumption is true that the algae cannot use the fixed carbon dioxide that makes up a normal carbonate, then carbon dioxide under those circumstances would become a limiting factor. However, it would only be temporary, because carbon dioxide exhaustion takes place only when a pond is green with algae.

It is rather difficult to determine exactly the amount of plankton which is produced in a pond containing fish. I thing the best way of measuring the productivity of such a pond is to count and weigh the fish.

So two summers ago we conceived the idea of carrying on some of the

fertilizing experiments in ponds that did not contain fish. These figures of the plankton represent for each pond averages of between seventy and eighty samples, taken within an interval of approximately four months. (Dr. Wiebe presented tabulated figures.)

It is interesting to note that although botanists say that Pandorina does not occur in waters containing considerable lime, we got in water containing lime from cement, an almost pure culture of Pandorina and Pleodorine, almost to the exclusion of other forms of algae. The Pleodorine ran as high as 960,000 to the liter and the Pandorina as high as 756,000. I do not know whether the Pandorina were not aware of the fact that they were not supposed to live in water containing lime. Six ponds, three in one row, three in the next, were filled with the same volume of water at the same time, from the same source. Pleodorine and Pandorina did not occur except to the extent of a few individuals in the control pond, and they did not occur at all in the other fertilized ponds where shrimp bran and soy bean meal and sheep manure had been used.

Our fertilizer experiments show significant differences in the amount of plankton that is produced in a fertilized pond and one that is not fertilized. The same is true of our data on the fish, yet I should hesitate to say why it was, or present an explanation. In the pond fertilized with shrimp bran the production of crustacea was not as high as might have been expected, and was not commensurate with the amount of algae. Shrimp bran, tends to run high in chlorides. The water in this pond contained as much as twenty-one and one-half parts per million of chloride in solution, whereas the other ponds ran from a minimum of a part and a half to say four parts per million. Is it possible that these fresh water organisms could not stand that relatively high degree of salinity?

Mr. P. Viosca (Louisiana): What length of time did it take to perform the whole experiment?

Dr. Wiebe: Approximately four months, beginning in June and ending early in September.

Dr. J. Van Oosten (Michigan): Has Dr. Wiebe any idea as to the amount of variation he could expect in his control ponds? I have noticed in our experimental work that where we used six controls we got a tremendous variation in those controls. If you had two control ponds, one might give you figures four times as high as the other.

Dr. Wiebe: I would not question at all that possibility. I am merely giving the figures we have obtained. Of course we have some other ponds which are not fertilized but which have fish in them.

Dr. Emmeline Moore: If you tried the same experiment next year, would you have about the same results in your fertilized ponds?

Dr. Wiebe: Not necessarily. Even if they were quantitatively similar, they might be entirely different in composition. We have a pond without fish that is

being fertilized off and on with superphosphate, and the algae are not Pleodorine or Pandorina. I might say further that in some of the fish ponds under the same treatment one year we will get an enormous growth of Aphaizomenon and another year an enormous growth of Anaebena.

MR. J. WICKS (Minnesota): It is apparent from your use of fertilizer that it stimulates fish growth and is a good thing. But is there not some danger of overdoing it? Can you give any direction to a layman as to the amount of fertilizer that ought to be applied to a pond?

DR. WIEBE: We have been aware of the possibility that we might be adding so much fertilizer that we would deplete the dissolved oxygen. Of course if you deprive the fish of the necessary dissolved oxygen it could not live. I cannot give offhand the exact amounts we are using, but we have never discovered that we were overdoing the fertilization. Of course the question is complex. This last summer I took oxygen samples the day before the fertilizer was applied, took it again the day it was applied, and again the day after or a couple of days after. In one pond I found that the oxygen had increased during that time, in spite of the fact that the fertilizer was added. The explanation was quite obvious: the bottom of the one pond was covered with vegetation which was affected by the sunlight and produced more oxygen than was consumed by the oxidation of the fertilizer, whereas in the other pond which did not have that vegetation the only oxygen available was the oxygen dissolved in the water.

PRESIDENT CULLER: Possibly Dr Davis could give you an approximate rule, Mr. Wicks, as to the amount of fertilizer that should be used in a pond.

DR. H. S. DAVIS (Washington, D. C.): It depends a great deal on the local conditions, in the various ponds. I do not consider it advisable to publish any arbitrary figure.

DR. WIEBE: We are using, on an acre pond, twenty-five pounds of soy bean meal, applied every five days. We have never applied twenty-five pounds of soy bean meal to an acre before, but when we take out the fish next month we may be able to tell you how successful it proved. Here is another pond of one-half an acre in which we are using twelve pounds of soy bean meal and four pounds of superphosphate. In another pond a little less than half an acre we are using nine pounds of superphosphate.

DR. VAN OOSTEN: May I ask Mr. Wicks a question, concerning the vegetation in the bass pond to which he referred? Did he put any water plants in that pond when it was started, or is the vegetation simply that which was there naturally?

MR. WICKS: We have nothing but a meadow which was flooded with water. We had a tremendous natural growth of algae.

DR. EMMELINE MOORE: Of course the algae would produce a tremendous turnover in fish food.

MR. WICKS: That fact is quite apparent from the results we had the first year. We would like if possible to get some practical directions as to the amount of fertilizers to apply to our pond.

DR. DAVIS: There is not nearly as much danger of over fertilizing with commercial fertilizer or sheep manure as there is when you use stable manure. I know of one instance during the present year in which the use of stable manure in ponds caused serious injury to the bass.

MR. CANFIELD (Minnesota): While Dr. Wiebe's paper has furnished a lot of new information, practical fish culturists will understand that he is still experimenting and is not yet ready to make a definite statement as to what quantity of fertilizer is to be used in particular instances. That recommendation will come eventually.

MR. G. BERG (Indiana): I would like to ask Dr. Wiebe if he has ever used menhaden meal. We used it last summer, with only moderate success.

DR. WIEBE: No, we have not used any of the meals. We have tried it in feeding experiments, but not in the straight fertilizing. It should be fairly rich in phosphorus.

MR. BERG: What is the cost of the soy bean compared with the fish meal.

DR. WIEBE: I think we have been buying it as low as three and a half cents a pound.

THE UTILIZATION OF SLOUGHS IN THE UPPER MISSISSIPPI WILD LIFE AND FISH REFUGE AS FISH PONDS

By Eugene W. Surber

Special Investigator, U. S. Bureau of Fisheries.

An investigation into the possibilities of using sloughs in the overflow land of the Upper Mississippi Wild Life and Fish Refuge as fish ponds began last year with a survey of the bottom lands lying between the foot of Lake Pepin and the mouth of the Wisconsin River.

The purpose of the investigation, under the direction of Dr. H. S. Davis of the United States Bureau of Fisheries, was to discover sloughs which could be used for the culture of bluegill sunfish, bass or other desirable species. At the same time collections of fish, plankton and bottom fauna were made in several localities. The results of these studies afforded an idea of the life which occurs in the sloughs. This year actual experiments in the utilization of sloughs were begun. Quantitative collections of the bottom fauna and plankton have been made at intervals of two weeks throughout the summer in order to obtain definite ideas of the natural food produced in the bodies of water which are to be utilized. Likewise oxygen, carbon-dioxide samples and temperatures were obtained to aid in affording the proper scientific background.

It will be necessary to explain just what type of sloughs has been selected for the experiments. They are bodies of water all under six acres in area, which exist in the old beds of chutes from the main channel of the river. These old chute beds have been filled in to a greater or lesser extent by sedimentary deposits. In one instance one may find a series of ponds located end to end at this time of the year; in another, only a single pond isolated from the river or adjoining sloughs. Most of the water areas in the flood plains are areas inclosed by alluvial deposits behind and between wing dams or closing dams which have been constructed across major chutes to prevent the river from taking a new channel. Such places are usually shallow and contain dense growths of vegetation locally called "coon-tail" or "moss," (*Ceratophyllum demersum*).

There are certain aspects in the behavior of the river and in the morphometry of the sloughs which determines which of these can be used for fish ponds. The entire bottomlands with the exception of a few high places, usually near the upper ends of islands, are subject to overflow at least once during the year. This is in the spring following the melting of the snow. A June rise may or may not occur depending on the amount of rainfall during the late spring season.

Another rise may occur during the rainy season in the fall, but this is relatively unimportant. Oscillations in the water level of the river and correspondingly in the water level of the sloughs may occur during the summer with heavy rains of general extent in the territory adjacent to the river or its tributaries.

It has been important to select sloughs with high banks. The low places in the banks, usually at the upper and lower ends, are screened to prevent the river and carnivorous fish from invading the section set aside for fish cultural use during a relatively high rise. The banks of the sloughs are not too steep to prevent or discourage the spawning of fish. The depth of the sloughs must be such that they will not become too shallow or dry up during the low water period in the summer. The shores are regular enough in outline and relief to allow complete seining in order that most of the carnivorous fishes may be removed. Such sloughs may be found at many points in the Refuge. Eight sloughs with the requirements named above have been improved in the vicinity of Trempealeau, Wisconsin, and Winona, Minnesota.

The improvement work on these natural ponds has consisted principally of cleaning out willows or other brush and drift that would make difficult the landing of a seine during the period in the spring when the water is still high. This is necessary since a state of relatively high water may exist up to and into the spawning seasons of the large-mouthed black bass and the bluegill sunfish, probably the only two species which may be propagated, since other desirable species of fish have spawned by this time. The low water stage at the present time is permitting us to improve on nature in providing spawning beds of gravel where only silt or mud are furnished in desirable places where the slopes of the shores are more gradual. These gravel beds are being planted above the present surface of the water since the river has dropped over three feet since the past spawning season for the black bass and bluegill.

The screens which are used to fence off low places likely to be invaded by the river during a rise, are portable and may be removed readily in the fall, in order to prevent destruction by the ice. The frames are built of 1″ x 3″ light pine lumber, are six feet long and four feet high. Seven mesh, No. 24 gauge galvanized screen of 48 inch width has been used in their construction. The screens are held in place and the spaces between adjoining screens are closed with eight inch ship lap lumber which is driven into the bottom and nailed to the screen with as few nails as possible. A double tier of screens may be used in greater depths of water. These, however, require ship lap twelve feet long.

Since the sloughs which can be used as fish ponds are long and narrow (none exceeding 200 feet in width) a single slough may be divided

into two or more ponds by the use of screens. Two such ponds were made of Gibb's Slough (area 2.82 acres) situated in an island opposite Trempealeau, Wisconsin. One hundred thirty-five large bluegill sunfish were placed in the lower half section of this slough while the upper half remained empty for the lack of brood fish. After the large sunfish had spawned many of the young worked through the screen into the upper half of the slough, where they had access to greater foraging grounds.

The general procedure in the utilization of the sloughs will be as follows:

(1) The introduction of screens into desirable sloughs as early as possible in the spring to prevent the escape of brood fish from the pond and also the entrance of carnivorous fishes from the river.

(2) The removal from the pond of all fish of a carnivorous or competitive nature.

(3) The introduction of brood bass or bluegill sunfish and forage minnows.

(4) If necessary, the fertilizing of ponds may be resorted to in order that the supply of food may be increased.

(5) The brood bass and bluegill sunfish will be removed in the fall and retained for further use while the fish raised will be freed in the river.

One important phase of fish culture in the sloughs will be the control of vegetation. Some more economical means of controlling the vegetation than that by hand should be found since it is several days work for a crew to clean the vegetation out of one of these sloughs. This ordinarily must be done at the very beginning of season when the carnivorous fishes are removed. Preliminary experiments this summer with sodium arsenite weed killer indicate that this chemical may be used effectively at low cost in controlling submerged aquatic plants without doing apparent injury to either large or small fish and without exterminating or seriously diminishing the supply of natural food.

The removal of carnivorous fishes from these natural ponds is such an important phase of the work that it deserves special note.

Below is a table showing the number of fish removed from three sloughs which were cleaned out this summer in preparation for the introduction of brood fish. In conducting the work in the long sloughs such as Frank's Bay and Richmond Pond, seines of quarter inch mesh are stretched across them and the section between seined several times with a quarter inch mesh seine of eleven or twelve foot depth. Even then it is not possible to remove all of the fish. There are small minnows which escape through the meshes of the seine; others, like the carp and bullheads work underneath and a few bass and pickerel may escape

over the top of the seine. A record, as accurate as possible, has been kept of the fish populations removed from these sloughs. Careful estimates were resorted to in cases where large numbers of small fish were obtained in a seine haul but errors due to these estimates probably do not exceed 20 per cent. Minnow species were not enumerated in Frank's Bay where they were left for forage purposes during the summer.

RESULTS OF AN INVENTORY OF THE TOTAL† FISH POPULATIONS OF THREE SLOUGHS IN THE UPPER MISSISSIPPI WILD LIFE AND FISH REFUGE

	Richmond Is. Pond Area: 1.94 Acres Richmond, Minn., Aug. 21				Pigeon Is. Pond Area: .73 Acres Richmond, Minn., July 20				Jack Slough (Frank's Bay) Area: 2.88 Acres Trempealeau, Wis., June 4			
	0–3"	3"–5"	5"–|–	Any Size	0–3"	3"–5"	5"–|–	Any Size	0–3"	3"–5"	5"–|–	Any Size
Lepisosteus platostomus Raf., S. N. Gar.											1	
Amia calva Linn., Dogfish			5				2				10	
Minytrema melanops Raf., Spotted Sucker			5								35	
Moxostoma Lesueririi Rich., Red Horse												24
Cyprinus Carpio Linn., Carp			1								3	
Notropis heterodon Cope. Black-nose shiner				8								
N. hudsonius Clint., Spot-tail minnow				15								
N. Atherinoides Raf., Lake Shiner				8								
Notemigonus Crysoleucas Mit., Golden Shiner				7,574				882				
Ictalurus punctatus Raf., Channel Catfish											5	
Ameiurus sp., Bullhead	24	23*						2,800§				26
Leptops olivaris Raf., Mud cat							1					
Umbra limi Kirt., Mud minnow				7				10				
Esox lucius Linn., Pickerel		46	167			140	22			224	130	
Perca flavescens Mit., yellow perch	705	531*			1,320	56*			906	34*		
Stizostedion vitreum Mit., Pike			5									12
Schilbeodes sp., Tadpole cat								4				19
Boleosoma nigrum Raf., Johnny Darter				2								37
Poecilichthys coeruleus Stor., Rainbow Darter				8				8				2
Aplites salmoides Raf., L. M. B. Bass	119	80*			234							28
Chaenobrythis gulosis Cuv. and Val. Warmouth Bass	26	35										2
Lepomis humilus Gir., Orange spotted sunfish	42	78						1				11
L. incisor Cuv. and Val., Bluegill sunfish	3,187	1,922*			229	88*			12,360	134	179	
Eupomotis gibbosus Linn. Pumpkinseed sunfish	364	255				8*						4
Ambloplites rupestris Raf. Rock Bass	4	4										1
Pomoxis annularis Raf., White Crappie												18
P. sparoides Lac., Black crappie	354	161*			1,867	17*			5,715	100*		
Labidesthis sicculus Cope. Brook silver-sides				91								
Lota maculosa LeSueur, Burbot							1					
Grand Total	15,856				7,690				20,020			

*Three inches in length and upward.

§Most of these are less than three inches in length.

†Total fish population is used here provisionally since it is probably impossible to remove all fish. The fish enumerated by us were those obtained in seining these places several times with a seine of sufficient length to stretch across the width of the slough and of depth to reach the bottom. Quarter inch mesh seine was used.

An examination of this table besides giving an idea of the kinds and number of fish found in these places reveals a serious competition for existence among the species of fish making up the population. For example, the total fish population removed from Richmond Pond, near Richmond, Minn., was 15,856, which included 167 pickerel of fish eating size. These voracious fiish could in three months' time during June, July and August consume 96% of the total fish population recorded if each pickerel consumed only one fish every twenty-four hours and did not eat their own kind. Similarly, 22 large pickerel were removed from the Pigeon Island Pond, also near Richmond, Minn. These fish potentially may have accounted for 26% of the total fish population in the same length of time. Likewise, in Frank's Bay in Trempealeau, Wisconsin, 130 large pickerel may account for 59% of the total fish population recorded. Here, however, the minnow species were not enumerated. It is probable that the large pickerel would not pay much attention to them with the larger perch and sunfish available.

From this, as well as other available data, it may be concluded that the pickerel is the most important fish enemy to be dealt with. Accumulation of more data may show that it will be desirable to affect legislation to permit the taking of this fish by commercial fisherman, since it is not esteemed as a game fish along the river in this section. If only such carnivorous fishes as the pickerel, dogfish and gars were removed from the places screened off it would undoubtedly do a great deal to increase the output of these ponds in game fish.

The scarcity of the large-mouthed black bass in these sloughs is very striking. It was hoped early last spring that enough large adult black bass could be obtained in four sloughs to stock at least one pond. Six large bass was the total taken. The bluegill sunfish was then resorted to for brood stock during the current year. The misfortune encountered above can not happen next year since two spring fed holding ponds have been developed at Trempealeau, Wisconsin, where adult bass can be held through the winter and the period of high water in the spring with safety. Should the river be slow in dropping in the spring, it is believed that the spawning time of the bass and bluegills may be retarded in the spring water until such time as it is convenient to introduce the brood fish into the sloughs.

If it should happen that the river remained at a high level until well into the spawning season it will still be possible to use these places as nursery ponds for young bass.

IX.—Discussion

Mr. Eugene Surber: Sloughs are hard to describe. They vary in character; some are still directly connected with the Mississippi River, and others

are merely isolated ponds occurring in the islands and bottom lands of the Mississippi River.

MR. W. T. THOMPSON (Montana): In the interior of the country we are spending thousands of dollars in the construction of ponds. On the upper Mississippi, situated under the most favorable conditions, are hundreds of acres that are ready and waiting for the application of intelligent effort. Mr. Surber did not say anything about the amount of bottom fauna in these areas.

MR. EUGENE SURBER: I know that the study of the bottom fauna should receive more attention than it has received in the past. I have collected bottom samples throughout the summer along with my plankton samples, and although I have not gone through my collections I can say that the number of bottom crustacea must equal or even exceed the larger entomostraca in the plankton samples. In collecting bottom samples I have used the Peterson grab, which has been employed extensively in marine work. The sample is placed in a tub in which water which has been strained through a 15-mesh sieve is poured. Then the water is decanted off the bottom sample in order to obtain the thousands of entomostraca that occur in the mud above the bottom. After the decanted water is concentrated, you can hold the bottom of the bottles containing the samples up to the light and see hundreds of entomostraca in the sample. In the case of a ten or fifteen liter plankton sample held up in the same manner, you can see relatively few entomostraca. We cannot rely on plankton samples alone to give us an accurate picture of the quantity of entomostraca produced in ponds.

DR. M. J. JOHNSON: I would like to ask Mr. Surber if his objection to the vegetation is solely that it prevents a complete seining of the predacious fish. If it were possible to get the predacious fish and leave the vegetation, would you do that?

MR. EUGENE SURBER: I would prefer to leave out most of the vegetation, enough to allow the seining of the fish in the fall without going to this extra trouble of removing the vegetation again.

DR. JOHNSON: Do you not consider the vegetation, on the whole an advantage, except that it makes it impossible to seine completely?

MR. EUGENE SURBER: No; I think Dr. Wiebe's work in connection with his fertilizing experiments shows that large quantities of natural food can be furnished to the young fish without vegetation, and that the presence of excessive vegetation means that chemical elements in the water are being removed which otherwise would be incorporated into the bodies of the plankton crustacea.

DR. JOHNSON: You are inclined to minimize, more or less, the importance of vegetation as a means of furnishing shelter?

MR. EUGENE SURBER: Yes. Large numbers of water bugs, as *Belostoma flumineum* and *Benacus,* occur in this vegetation when it is taken out of the

sloughs. I do not know whether this bug consumes many small fish but I imagine it might. Where the vegetation is present in great abundance, as it usually is in these places, it might afford an excellent place for the enemies of small fish to congregate.

President Culler: In the slough near the mouth of the Trempeleau you took out fifteen or sixteen thousand fish?

Mr. Eugene Surber: Over twenty thousand. We must have taken out in addition at least twenty thousand shiners.

President Culler: In that same pond what could you expect under control conditions?

Mr. Eugene Surber: The average production per acre in the nursery ponds at Fairport is about seven thousand fingerling bass and about twenty-two thousand bass fry. The area of this slough is 2.28 acres, so that we might expect to get somewhere near fourteen thousand fingerling bass. Fourteen thousand bass surely would be more desirable than a similar number of bluegill, sunfish or perch or any other game fish that were left there naturally. The data I have collected on the total fish populations and the possible effects of the pickerel being left in the sloughs would seem to indicate that it is highly desirable even if we did nothing else but take out the pickerel.

SOME EXPERIMENTS IN REARING CHANNEL CATFISH

By Alva Clapp

Kansas State Game Warden

As fish men we tend to spend entirely too much time and money catering to a small percentage of the men who pay the bills for fish cultural work. I do not believe that five per cent of the people in the Mississippi valley are fly fishermen, or men who go in for game fish such as trout and bass. It is possible that we are forgetting what Max Hart calls the one-gallus fellows and devoting ourselves to the interest of the golf player and the aristocrat. If so, I am not sure that we are doing the right thing.

In our section of the country the most universally distributed fish is the channel catfish—the forked-tail cat, the spotted catfish. Many people say to me every year: "I would rather have a channel cat as a table fish than any other fish in the world." They are a fishy tasting fish—I will admit they are a little bit too fishy for my palate, but I like them. They are certainly a good fish to catch, and as I say, they are universally distributed. Because Kansas has no trout it has undertaken to develop this wonderful fish, and perhaps it has done a little bit more along this line than any other state in the union.

We are a prairie state. We have numerous sloughs running through the country, and the farmers will throw a dam across these sloughs in the prairie and impound from half an acre to fifteen or twenty acres of water. Channel catfish taken from the streams and put into these ponds grow wonderfully, but they will not reproduce. However, in one fifteen acre lake in which seventy channel cat from the Madison River were introduced literally thousands of channel cat were taken, contrary to all our previous experience. On investigation there were found in a sunken motor boat spawning nests of catfish and it was decided that in order to reproduce these fish needed nests in which to deposit their eggs.

We had in our hatchery about seventy brood fish that were brought there by Professor Dyche in 1914. Hatchery records indicate that we have spent probably $40,000 with the idea that channel catfish reared their young only in swift running water. These fish were placed in Pond No. 1, where the water first comes in through the pipe line into the hatchery. The sides of the pond sloped down to one point so that by opening a valve it could be drained. As an experiment I gathered old tile, beer kegs, nail kegs, boxes, etc., and bedded them in the banks, with the open end toward the center of the pond. The first year I put a shovel full of gravel in the bottom of each nest and bedded them at all depths, from five feet up to a foot or two. The fish occupied those kegs but they cleaned out all the gravel before depositing their

eggs, and we hatched literally thousands of young catfish. They were so thick that I could dip a ten inch dip net anywhere in the pond and taken out ten or fifteen. But when October came we did not have a fish. Apparently the old ones had eaten them. So the next year I placed some kegs only about six inches under the water, but it did not seem to make any difference whether they were located deep or shallow; the fish showed no preference. I cut out and hinged the tops of a couple of kegs and made a water-glass, so that I could look into those kegs and see what was going on.

When the little ones hatched they remained in groups for a while. They went in and out of the keg. It was found practically impossible to remove the brood fish from these ponds by seining because of the muddy water, so we had to try other methods. The next year we placed our kegs at a uniform depth throughout the ponds. When the little fish were hatched we lowered the water to about half the depth of the keg. We removed the fish from the kegs with dip nets and transferred them to a clean pond, thus saving about 40,000. The work has been carried on largely by our fish culturist, a fine, energetic young fellow, who now takes the spawn from the kegs. He prepares the kegs just the same, and he makes rounds every day with a canvas bucket to gather the spawn.

We have arranged a hatching house, very much as for trout hatching, with a series of troughs twelve feet long. The spawn is placed in an eight inch mesh hardware cloth cylinder which fits well down in the trough. In the trough five paddles of galvanized iron are attached to bars across the trough. An electric motor which was first tried gave a uniform impulse to the water and proved unsatisfactory. It was replaced by a twenty-four inch water wheel. A three-inch water line comes in and a two-inch pipe runs out on each side, with an eight-inch nipple on the end. One of these nipples pours the water into the trough and keeps it running through. The other one pours water on to the water wheel. The cups on the water wheel gradually fill and it will make a sudden jerk which will throw the paddle over suddenly. Then the wheel may hang for a minute or two minutes, but when the cups become full of water again it will make another irregular jerk. By this method we can hatch one hundred per cent of catfish eggs.

We could raise catfish by the million if we could feed them. We do not know what to feed them. We have experimented with every food we can obtain—blood, liver, heart, buttermilk, peas, menhaden meal—everything we can think of but they do not thrive in those troughs beyond about three weeks of age. But even at that we are improving on nature. I have prepared a lot of ponds to receive these fish. When hatched the young catfish are removed from the troughs to these ponds at the rate of about 20,000 fish to an acre pond, not merely an acre of

water, but an acre of water plentifully supplied with vegetation and everything conducive for the cultivation of young fish. They do well until they are from four to four and a half inches long, but we cannot produce large numbers without more rearing ponds.

The channel cat is a warm water fish. I do not believe a temperature of ninety degrees will affect it. The water in which the eggs hatch has a temperature of about seventy-two to seventy-six. It is not clear water; it is roily water and roily water does not seem to injure them at all. If you put the eggs in well water which has an initial temperature of sixty degrees, under the same conditions of troughs, paddle and everything else, after about thirteen or fifteen days, white fungus will attack the eggs and they will not hatch. If we run well water into the pond and raise it to sixty-five degrees, the eggs will not hatch.

Actual count of one nest of eggs showed a little less than 38,000 eggs. The average, I would say, is about 15,000 to 20,000 eggs. The eggs are light yellow or tan, and they look like steamed tapioca, being about the size of a very small pea. As they near the hatching stage they darken and take on a maroon tinge. You can tell about how old the eggs are by the color. In our warm water they hatch uniformly in about five days.

Discussion

MR. HEUCHELE (Ohio): Are the eggs glutinous at the time they hatch?

MR. CLAPP: Yes. It is possible for these channel cat to hatch their eggs in swift running water. I have observed eggs attached in the six inch water pipes which supply the pond with water when these pipes were full of water flowing into that pond. The current was not strong enough to wash them out. They are in a mass. You cannot run your fingers through them like trout eggs, but you can pick the mass up and flip it around like a pancake, without injuring the eggs.

MR. MANNFELD (Indiana): I should like to ask Mr. Clapp whether the channel catfish does not eat its own eggs.

MR. CLAPP: In our aquaria the fish will eat the spawn in a day or two. That is why we gained by taking the spawn away from the adult fish.

MR. MANNFELD (Indiana): Our foreman at the Indianapolis station has been working on the channel catfish for some time. This year we succeeded in putting out 21,000 two and a half to three inches long. We hope ultimately to increase the production. We have something like fifty or sixty brooders, but we get only about five or six nests. They are a very difficult fish to handle. We came to the conclusion that the old fish destroyed the eggs.

MR. TUCKER (Texas): Have you tried placing pairs of catfish in separate pens?

MR. CLAPP: No.

Mr. Tucker: That is the method we follow in Texas; we place each pair in a separate pen. The little fish come out of the keg naturally after the yolk sac has been absorbed. We find that if we attempt to feed the little catfish before the yolk sac is absorbed, we have a large number of fatalities.

Mr. Clapp: What percentage do you think you recover in that way, three and a half to four inches long?

Mr. Tucker: Well, it would be a hazardous guess.

Mr. Clapp: This year we took just about fifty spawn, and my estimate is that we actually hatched 500,000. We are far enough along now to enable me to say that we will recover about 128,000 fish this fall that will be approximately four inches long. That is better than they will do in the open. Last fall I visited one of our streams which was literally alive with little channel cat about an inch and three-quarters long, yet that body of water is not a very good channel cat stream. Evidently they die naturally in the stream, so we are improving a little on nature.

Mr. W. T. Thompson: What is the approximate size and weight of these fish that gave from three to four or five pounds of spawn?

Mr. Clapp: We have channel catfish that will weigh fourteen pounds. We have about one hundred and twenty-five each year coming on that will weigh three to three and a half or four pounds. I suppose the large masses of eggs are laid by fish weighing nine to ten pounds.

Mr. Tucker: Do you have any trouble with tapeworms in catfish?

Mr. Clapp: The only thing we have had in our hatchery is a disease we call blotch.

Mr. Tucker: What do you do for the blotch?

Mr. Clapp: We just put a strong flow of water in the troughs. The cysts burst open and are washed away.

Mr. LeCompte: The Mississippi catfish was introduced into the Potomac River in 1917. They not only eat their own spawn, but they destroy the spawn of the bass, a decided objection. They grow to a large size in our water; they have been caught there weighing twenty-one pounds. The Washington County fishermen have devised a means of catching them. Instead of using a hook they cut a piece of Octagon soap into four pieces, tie it to their line, and I am informed that the catfish take this lure more readily than a minnow or any other bait.

President Culler: With regard to the size of the catfish, I have seen in the Atchafalaya region of Louisiana catfish that weighed seventy-six to seventy-eight pounds.

Mr. Clapp: Of course all the fish grow larger down south. The further north you go the smaller they are.

A TRAP FOR THE CAPTURE OF LARGE-MOUTHED BASS FRY AND FINGERLINGS

By Herman O. Hesen

Superintendent U. S. Fisheries Station, Louisville, Ky.

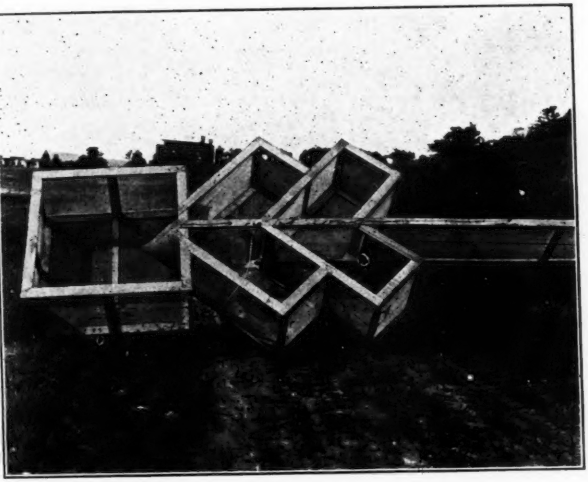
Introduction

Man has always been interested in devising methods of capture of fish. This interest, of course, has been of special significance in commercial fisheries. It has also, however, been the cause of the development of certain methods applied almost entirely to the field of artificial culture and handling of fishes. This paper deals with one such method recently developed and applied to the capture of fingerlings and fry of the large-mouthed black bass. The history of the artificial culture of this species has been characterized by a general lack of efficient methods of capturing and removing the broods of young as they develop. This unsatisfactory situation was the stimulus for the experimental development and later practical trial of a trap herein described.

The Handling of Bass Fry and Fingerlings

An early practice in bass culture was to drain the brood pond as early as practical and collect the young fishes by dipnet wherever possible or to collect them from muddy banks and algae by hand. Necessarily the drawing of the pond, involving a loss of water, forage animals and plants, and the larger aquatic plant growths, entailed considerable expense, not to speak of the killing or injuring of many fry or fingerlings. In other cases the fishes, adults and young, were allowed to remain in the ponds until late fall when collection was commenced. Under such conditions, in view of the cannibalistic nature of the species, the number of fingerling fishes surviving tended to be greatly reduced. Of course, this situation is obviated by the early distribution of fry or by their removal to rearing ponds previously supplied with an abundance of natural food.

The fact is that the continued demand for bass and the excessive loss through cannibalism has made fry distribution imperative. Fry must be distributed or reared in specially provided ponds. Hence, they must be caught preferably while in the fry stage. The early methods of capturing bass fry are more or less generally employed today. Drawing ponds early, gathering all fishes possible, then refilling the ponds promptly to care for those not captured or killed by the operation is still an accepted practice. Another is the use of a bass fry retaining screen provided with a trap as described by A. E. Fuller, September 1908, Fourth International Fishery Congress, Washington, D. C. Or again, seines with light bamboo poles, as brails, are cast from the bank of the



A TWO-WING TRAP

THE TRAP IN OPERATION

pond and hauled. Large round long-handled dipnets, covered with cheese cloth are also commonly used, or indeed ordinary short seines, made of bobbinet. These methods of collecting bass fry or fingerlings have many obvious disadvantages. First, their cost is not commensurate with the results obtained. The items of time consumed in the operations, men employed, equipment required and fish lost, are significant in this view-point.

In employing the usual old but accepted methods it is necessary for one or more men to spend many hours rowing about a pond in search of nests over which young fishes are "swimming up" of sufficient size to justify catching. Then after locating the fishes if dipnets such as have been referred to are used, only a few quick dips can be made before the young fishes are scattered or the water so roiled that even fry within reach can not be seen, moreover, nearby nests of unhatched eggs may be damaged or disturbed in the collection of but a few hundred fry. Thereafter the escaped fishes become wary at the slightest sound or approach of men on shore or in boats, secreting themselves among the plants or other places of shelter and making further attempts to capture them almost valueless.

After bass fry have schooled and start swimming a seine may be used. This operation requires quick, alert employees, men who are not afraid to jump into the water, even if more than waist deep, and regardless of its temperature. Quickness of operation counts, for those fishes that are not taken in the first haul are, for the time at least, lost. This is a "hit or miss" operation. Three men at least are required when a seine is used, two with the seine, one with the boat and equipment. When the school has been located, if not in water over neck deep, two men jump in and endeavor to catch them. However, with the splash of both men into the water and other attendant noises the school becomes so alarmed that its members seek immediate safety elsewhere. Another impediment to seining operations is pond vegetation and algae. Even should the operators have the good fortune of surrounding the entire school, the vegetation is often so thick that the seine rolls and the fishes are lost or the few caught are injured. At other times large quantities of plants are uprooted and remain in the seine, weighing it down so that a quick haul cannot be made and only a small percentage of the fishes seen are taken.

This is a very unsatisfactory, inefficient, destructive and laborious task, and without question injures and kills many young fishes and ruins much plant life. The necessary wading also does an irreparable damage not only to possible later nests, but also to the plant life of the pond. Then too, areas of the pond bottom so harmed may have been already chosen for nesting purposes by adult fishes about to spawn. They may not be able to use them after the damage has been done. Or a good feeding ground may have been ruined.

The seine operated from the pond embankment has a distinct advantage in many respects, over such seining operations as have been mentioned. But it is my opinion that it is not so thoroughly effective. Such a seine is awkward to handle and requires much practice and experience to make it effective. The young fishes too can escape easily around its ends as it is being hauled to shore; more easily in fact than from the ordinary seine. In instances where fry are located over dense vegetation, it is practically useless to cast it out because of the probability of its fouling.

The New Trap for Large-mouthed Bass Fry and Fingerlings

Appreciation of the disadvantages and limitations of these several methods of collecting and removing bass fry and fingerlings from brood ponds led to the experimental construction and operation of fish traps with adaptations for this purpose. Later a trap developed from this experimentation was used practically on the bass ponds of the U. S. Fisheries Biological Station, Fairport, Iowa, with uncommonly satisfactory results. These will be discussed later.

The trap consists of a wooden frame "lead" sixteen feet long, two feet high, made of one by four inch dressed fir. An inch strip is nailed to the center of the "lead", both top and bottom, the bobbinet is to be nailed on to this strip, not on the side of the lead proper. Two pairs of V shaped wings 45¼ by 24 by 28 1/3 by 24 inches high and a retaining box four feet square, provided with a funnel fourteen by twenty-four inches, funnel to be made of galvanized or copper screen, tapered to an inch hole. The throat opening of first wing is four inches on each side of the bobbinet, the opening of the second pair of wings is two inches on each side of bobbinet lead. The bobbinet used as a lead does not enter the second pair of wings. One by four inch dressed fir has been found very suitable for frame construction. The entire frame work of trap is two feet high. Bobbinet, previously treated with copper oleate to preserve is used throughout, with the exception of the retaining box bottom, which is covered with sixteen mesh screen wire. A partition made of one inch fir is placed across the retaining box at the funnel end. Cut an inch diameter hole in center of partition to allow the funnel end to fit snugly in. A bag made of bobbinet 30 by 45 by 24 inches with an inch hole cut in bag and reinforced with heavy material to prevent fraying. Tack this hole finger tight around funnel opening on the wooden partition enough to hold it smooth and tight enough to prevent fry from escaping. Along top edge of retaining box are placed small finishing nails, over which the selvidge edge of bag is fastened. Small lead weights are sewed around the bottom of bag to hold it straight down and in place.

During the experimentation a trap with one pair of wings made of 2 by 2 inch fir lumber was found to be satisfactory, but a two winged

trap is preferable. A trap made entirely of wire screen has been used, but this was too heavy and unless the wire screen was of copper, soon rusted out. A trap constructed of bobbinet is light enough for two men to handle with ease, and, with proper care, will last two seasons. Blueprints of the trap may be secured from the U. S. Bureau of Fisheries, Washington, D. C.

By using screws instead of nails wherever practical, worn out parts are easily replaced. The cost of traps made in Iowa average approximately $10.00 each. The trap, while light enough to float, is staked a few inches higher than the water surface (Fig. C.). This prevents wind or storm actions from doing damage to either fishes or the trap, and makes it more effective in the capture of bass fry swimming near the surface.

The Principle and Manner of its Operation

The principle of its operation and construction is similar to the common commercial pound nets used on the East coast, the floating salmon trap of the West coast fisheries and the contrivance described at the Denver meeting of this society by Mr. Murphree. He used a piece of ordinary sixteen mesh wire screen, of a given length, bent heart shape, and staked to the pond bottom, with a lead running to the bank. While the principle of the Murphree trap and the one here described is much the same, I am not aware of the pound net or floating trap, as used commercially, ever before being adapted to use for the capture of bass fry or fingerlings. The trap here described is different from that described by Murphree, and we think an improvement, in that it is of an entirely different plan and better adapted for surface swimmers; it is more durable in construction, has a permanent bottom and can be placed in any depth of water without increasing its height; moreover the presence in it of a bag for the removing of fishes as explained further on in this paper, makes this trap quite different from anything previously used for the purpose.

The manner of successfully operating this trap is to place it in the pond within a week after the first fry have been seen. This makes capture certain while fishes are still in "schools". It will not be so effective if the installation is later than this. It is imperative that the trap be set soon enough. To the proper timing of installation, above all other factors, may be attributed its efficiency in capturing large-mouthed bass fry. The lead is placed a few inches in to the embankment, with the trap proper suspended out in the pond. Due to the usual slope of pond embankments, and to prevent the top of the trap from dipping under the water, it is advisable to dig a narrow trench in the pond embankment deep enough so that the lead may be kept fairly level on the pond bottom for several feet out. This too, will prevent fishes from going

around end of the lead. The lead can also be pushed down in to the soft mud of the pond enough to allow the top of box or retaining end and wings to ride an inch or two out of the water. The wings and box must not be submerged. To render it immovable and to keep it in proper position, the trap is staked. Six pointed stakes of wood or round iron are driven into the pond bottom a sufficient distance to hold the trap at the specified height and position. Two stakes at each corner of retaining box, two on wings and two along lead are sufficient. If wooden stakes are used it is not necessary to nail the lead screen fast, but only sufficiently to hold it in place. The trap is placed at any favorable point in pond. In large ponds two or more traps may be used. The fry are caught regardless of the direction in which they are moving. However, bass fry usually swim near the shore, and from experience it has been found that a sixteen foot lead is the most effective. The trap as used to date has not been covered or darkened, but it is possible that some cheap material placed above the trap in ponds having no shade would be beneficial. There is no definite time limit a trap should be left in a pond. At Fairport the traps were not removed until practically all the fry were captured or at least the required numbers caught. The fry should be removed as fast as the number in retaining box justifies. At the height of the season, when the schools are large and active, it necessitates continuous work of one man during the day to remove, count and weigh the young fishes. The effectiveness of the trap as to time depends largely on the movements of the fishes. We have found shortly after setting a trap, when the fry were moving, that a steady stream of fry were pouring into the trap with thousands already impounded. Removal operations commenced at once, and continued for several hours. The trap works 24 hours a day, though very few fishes are caught at night. Bass fry are not swimming up during storms or windy weather and therefore, no fry are to be expected on other than clear calm days when they are on the move in search of food. In ponds where large hatches have been seen and where large schools of fry are anticipated, the trap should be visited morning and evening. From fifty to seventy-five thousand fry may be held in the trap over night without injury.

No provision was made with the first traps constructed for the removal of fry from the box other than by hand dipnets. This made the removal of thousands of fry quite a long operation. In order to remove all the fry by dipnets it was sometimes necessary to knock the stakes loose, lift the trap up a foot or two and tilt it to one side. The funnel extending as it does into the box, was always in the way, making it awkward for the operators to remove the fry. This condition has been overcome by introducing a bag made of bobbinet fitted in the retaining box. In order to use this lifting arrangement the compart-

ment was partitioned off just in front of the funnel. The fry go from the funnel directly into the bag, then instead of dipping them out, it is only necessary to slip the bag off the nails, remove the tacks around the end of funnel, gather the bag up gently, work all fishes to the center while still submerged, raise quickly, turn bag inside out in tub partly filled with water ready to receive the fry. Should there be fry in the wings of the trap, a cork is fitted into the funnel to prevent any from going into box while the bag is being emptied. The bag is returned to the box, fastened as first described, the cork is pulled and the trap is ready again. The bag arrangement is quite a time and labor saver, because to remove, say five to fifty thousand fry with dipnets required much time. Some injury was caused to the fry by being struck with the dipnet or by being caught between it and the trap frame. Now instead of handling many dipnets full of fry, but one operation is required, thereby reducing injury and mortality.

The Effectiveness of the Trap

Some concrete examples of the trap's effectiveness are cited below: On June 10, 1927, the first school of bass fry were seen in pond D4, with a water area of .987 acre. It had been stocked with 75 adult bass. About 3:00 p. m. June 12th, the first trap to be used at Fairport was placed in this pond. Nothing unusual was noted until the next morning about nine o'clock. It was Sunday June 13th and the man on duty told me that from that time until noon he was kept busy removing fry. When weighed and counted it was found that he had removed 34,730. A sufficient number of fry having been secured the trap was fished no more that year.

About 9.00 o'clock a. m. June 7th, 1928, a trap was placed in pond D5, size .983 acre in area. This pond was stocked previously with 25 brood bass. By noon the same day 39,700 fry had been removed, and by June 9th, 31,000 more had been captured. Thus a total of 71,000 fry had been trapped with no disturbance to young or adult fishes or to the pond.

During the forenoon of June 3rd, 1929, a trap was introduced in to pond D5 previously stocked with 24 adult bass, and by four o'clock June 4th, 98,000 fry had been removed from the trap.

A photograph taken June 13, 1927, shows a portion of the 34,000 fry taken on that date. It is felt, from our experience that the trap is more efficient on fry than on fingerlings.

Interested persons and fisheries organizations have been provided with information regarding the construction and operation of the trap here described. To date no reports are available regarding the effectiveness of the trap when used by other than federal employees.

Conclusion

It is felt that the trap described herein obviates the disadvantages of the several old methods of collecting bass fry and fingerlings in every respect. The cost of construction and operation is reduced to a minimum. It requires but two men to place a trap in a pond, a short job, and but one at intervals to remove the captured fishes. There is no loss of water by pond drawing or refilling. There is no loss of natural food or shelter. The injury to fish life and vegetation is practically eliminated. The water is disturbed only at the time when the trap is introduced, which is of the shortest duration and in a limited area. As a boat is used in placing the trap, no wading in the pond is necessary. The trap may be placed in the most dense vegetation without doing damage to plant, trap, or the trap's efficiency. It is felt that it is a vast improvement over any of the older methods of removing fry, both as to ease of operation, time and labor saved, cost and general effectiveness. After the trap has once been placed, there is no disturbing or interrupting of the activities of late breeding fishes or of the unhatched nearby nests of eggs. The trap commences to work immediately after setting it in place, and continues so long as there are schools of young fishes swimming. The young fishes impound themselves without any human effort being expended, as their natural instinct is to swim in large schools near the water surface. They are captured regardless of their movement provided they make contact with the lead. Cannibalism too, is greatly reduced because each school is caught practically in its entirety. By preventing two different age groups of fry from coming into contact with each other cannibalistic destruction does not take place. In this respect experience with the trap at the Biological Station, Fairport, Iowa, has shown the trap to have a distinct advantage, in that the fry collected from it are of a very uniform size. This is a very favorable and significant feature, for when they are placed in small rearing ponds, they generally maintain this uniformity of size, grow evenly, and when collected as fingerlings in the fall, require little or no grading for distribution.

XII.—Discussion

Mr. LeCompte (Maryland): May I ask Mr. Hesen what is the size of his trap?

Mr. Hesen: It is two feet deep, and it runs thirty by forty-five by twenty-four inches. The width would be ninety inches. The wings run on an angle, and the frame is forty-five inches long on the outside and thirty inches on the inside. The retaining box is four feet square and two feet deep.

Mr. F. W. Westerman (Michigan): Was it used for both large-mouthed and small-mouthed bass, and how late in the development were you able to use it successfully?

Mr. Hesen: It was never used on small-mouthed bass, because small-mouthed bass can seldom be taken in schools. After the required number were captured, usually we took the trap out. It is better for fry than for fingerling fish. The large-mouthed bass of fingerling size are scattered, but fry keep in a dense school. As they swim around the pond and come in contact with the lead, they follow the lead, strike the wings and from the wings pass through the funnel into the retaining box. At first the funnel hole was about three inches in diameter and the fish could turn around and pass out again. The hole should be not larger than an inch. That size prevents the larger fish, if perchance they should get in, from going through the funnel into the retaining box and eating the fry.

Dr. Metzelaar (Michigan): Did you say you handled bass up to three inches in length?

Mr. Hesen: No, the three-inch bass were not captured but were taken in the fall when the pond was drained. Between thirty and forty thousand fry and some seven thousand fingerling fish were removed from the pond last fall.

President Culler: Have you tried this type of trap in the land-locked sloughs or pools in the vicinity of Fairport in connection with rescue work?

Mr. Hesen: No. With this intention I made a trap on a larger scale, but last year the high water did not afford an opportunity for its use. I do not know of its ever having been used in the sloughs or land-locked waters.

President Culler: Two traps were constructed at Homer, but on account of the high water last year they were not used. Instructions were issued to the foremen, however, to try them this fall.

Dr. A. H. Wiebe (Iowa): Naturally it is desirable to get these small fish into the rearing ponds in good condition and with as little effort as possible. During the last three years at Fairport we have handled our fish by the use of this trap, with little effort and with the expenditure of little time.

Mr. Hesen: I feel confident that at places where similar conditions prevail the trap will do just as effective work as at Fairport.

THE RELATIVE VALUE OF PLANT AND ANIMAL BY-PRODUCTS AS FEEDS FOR BROOK TROUT AND THE BASIC NUTRITIONAL REQUIREMENTS OF BROOK TROUT IN TERMS OF PROTEINS, CARBOHYDRATES, VITAMINS, INORGANIC ELEMENTS, AND ROUGHAGE*

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NORMAL GROWTH RATES AND STUNTING OF BROOK TROUT

In our previous series of reports upon the nutritional requirements of brook trout we have shown that they conform to certain of the fundamental laws of nutrition inasmuch as they require a definite intake of protein for optimum growth. If protein is fed below this given level of approximately ten per cent they are stunted in growth but can resume a normal growth rate at any time the ration becomes adequate. After a period of stunting there may be an actual acceleration of growth which tends to effect a compensation. We have also shown in a series of studies that trout grow at a slower rate than many of the higher warm blooded vertebrates. This slower growth rate is characterized, however, by its remarkable uniformity, thruout the growing season.

In chart 1 we have presented data which confirms and expands our earlier conclusion. This chart shows the growth curves for representative individuals fed upon the diets recorded in table 1 throughout the entire period of the experiments. The technique of conducting our feeding has been described previously (1). Three years of experience have shown these methods to be very satisfactory. At the bottom of chart 1 we have plotted the temperatures for the waters inside the hatchery during a portion of the experimental period. At the bottom of the chart we have also recorded the dates so that the growth rates during the same period of two succeeding years can be compared.

The growth curves for groups 11 and 12 cover a period that exceeds two years. These show the remarkable uniformity of the growth rate throughout the growing periods of both years. They show the cessation of growth during the spawning period. These curves furnish standards for comparison of the growth rates of individual trout from

an initial weight of about four grams to a final weight of approximately five hundred grams. They show that the rate of growth between the first and second spawning periods is practically the same as that which precedes the first spawning period which represents the approach to

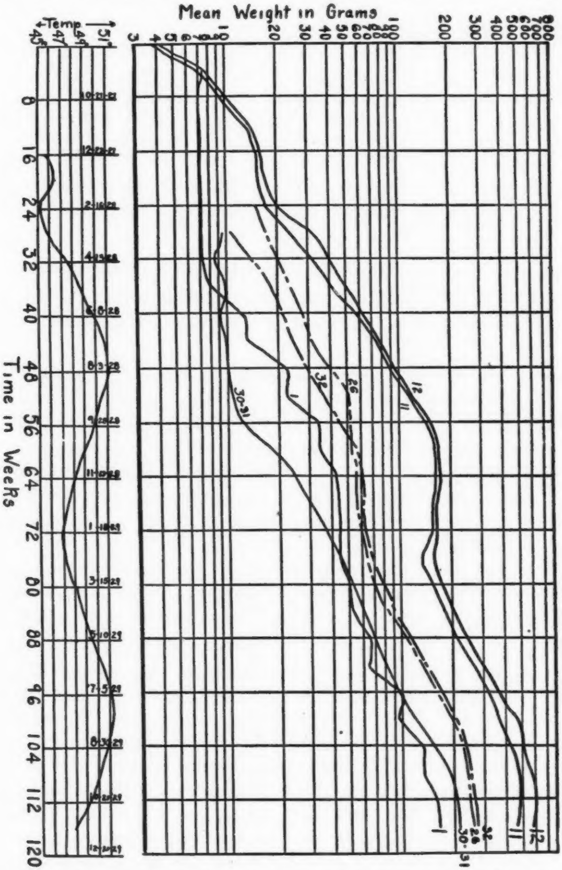

Chart 1. Growth curves for brook trout during a period of two years. Groups 11 and 12 were fed exclusively upon raw liver and dry skim milk. Group 26 received red dog flour and raw liver. Group 32 received peanut meal and raw liver. Groups 30 and 1 show the rates of growth after periods of stunting.

TABLE I

No. 1		No. 11		No. 12	
Casein	10	Raw liver	61	Raw liver	90
Starch (cooked)	82	Dry skim milk	37	Dry skim milk	7
Salt mixture	6	Cod liver oil	2	Cod liver oil	2
Cod liver oil	2	Yeast		Starch	1
Yeast				Yeast	
No. 26		**No. 31**		**No. 32**	
Red dog flour	65	Fish meal	24	Peanut meal	24
Salt mixture	3	Starch (cooked)	41	Starch	41
Raw liver	30	Salt mixture A	3	Salt mixture A	3
Cod liver oil	2	Cod liver oil	2	Cod liver oil	2
		Raw liver	30	Raw liver	30

By "salt mixture" we imply Osborne and Mendel's, while by salt mixture A we mean a simple composition of sodium chloride 1, calcium carbonate 1 and bone meal 1. Yeast was fed as described previously (3).

sexual maturity. Since both diets 11 and 12 contain dry skim milk, these data confirm one of our earliest conclusions that dry skim milk when supplemented with raw meat is a satisfactory growing ration for brook trout.

Curves 1 and 30 of chart 1 show the effects of stunting by two different methods, upon the subsequent growth of trout. Group 1 was held upon the low protein diet for twenty-eight weeks during which time there was no growth. At the end of this time the group was fed during one period of four weeks a diet of raw liver permitting them to grow. This was followed during the following four weeks by the low protein synthetic ration permitting no growth. This technique of alternately feeding, growing and stunting diets, was continued as the chart shows from the thirty-second to the hundred and sixteenth week. During the spawning period there was no growth upon either diet. This group shows very clearly the acceleration of growth after stunting.

Group 30 whose early history was described in a preceding publication (2) was maintained upon a restricted intake of raw liver for twenty-four weeks. This represents a common type of stunting due to insufficient calories. At the end of this period the group was changed to a good growing ration, No. 31, whose composition is shown in table 1. We had previously shown this ration to be capable of providing a growth rate equal to that obtained upon rations 11 and 12. The result of this experiment is shown in the chart. The growth rate was very uniform throughout the entire period from the fifty-fourth to the one hundred and twelfth week. This group passed through both the period when they would have spawned if they had not been stunted and through the extremes of water temperatures without alteration of their growth rate. This is of special interest since one would have expected

a decreased growth rate during the period of low water temperatures and an accelerated rate during the higher temperatures. This curve shows, however, an initial acceleration after the long period of stunting. Since this group was fed only ration 31 during the entire growing period of more than one year and since this ration contains a considerable amount of commercial fish meal it shows that this product has a place in practical trout feeding as a supplement for beef liver.

These experiments upon stunting followed by accelerated growth have a direct bearing upon the labor involved in the large scale feeding of trout and cleaning of troughs. Since trout tend to increase their growth rate after a period of under feeding one is led to wonder how much evidence exists to justify the numerous feedings to which the ordinary hatchery trout are subjected. Any radical change must be based upon adequate experimental evidence but such a change is a possibility in cutting the labor cost in hatchery operation.

In curves 26 and 32 we have shown the growth rates upon diets containing large amounts of wheat flour and peanut meal. These have been equalized in protein content by the addition of raw starch to the peanut meal. Neither cereal grain has been cooked. Both have produced moderate growth. As the curves show the results were considerably better during the second period when the rate was almost equal to that obtained with milk and liver of diets 11 and 12.

The mortality rates upon all these rations has been negligible. The groups were started with fifty fish upon each ration and this number has been reduced from time to time keeping the mean weight unchanged. The latter portions of these curves are based upon ten to twenty-five individuals.

Since the reliability of such experimental data depends upon the individual variations of the members that constitute a given group we have taken occasion when certain normal groups were killed after the termination of an experiment to determine the probable error after meticulous weighing of individuals. In table 2 we have incorporated a small amount of such data.

Table 2

Number of Fish in Group	Mean Weight and Probable Error
50	44.2 + or — 1.8
51	65.7 + or — 2.9
40	70.0 + or — 3.0

In any phase of the husbandry of animals where the ultimate destiny of the animal reared is to serve as a supply of protein for human consumption, man must concern himself with the efficiency with which the growing animal converts its feed. This is a major item in the cost of production of meat whether that meat is ultimately sold as chicken, beef, pork, or fish. In the course of our major experiments such as

TABLE 3

Diet No.	Weight Beginning in Grams	Weight End in Grams	Gain in Grams	Dry Weight Feed Consumed	Dry feed per gram Gain	% Protein in Feed	Protein per Gram Gain
12	3129.2	3455.2	326.	696.7	2.14	48%	1.02
	3455.2	3913.6	458.4	903.2	1.9		.91
	3497.3	4521.	1023.7	1147.5	1.12		.54
	4521.	5418.5	897.5	1292.9	1.44		.69
	5418.5	6200.	782.	2096.4	2.71		1.31
	6200.	7483.1	1283.1	2010.	1.57		.75
	7483.1	8100.5	617.4	1730.	2.8		1.34
26	1452.	1667.	215.	449.5	2.1	19%	.399
	1667.	1848.3	180.7	620.	3.4		.646
	1821.2	2240.	418.8	808.5	1.9		.361
	2240.	2823.6	583.6	1273.8	2.2		.418
	2823.6	3470.	646.4	1739.7	2.69		.51
	3470.	4153.3	683.3	1911.	2.79		.53
	4153.3	4658.8	505.5	1592.7	3.1		.59
11	3632.2	4219.5	587.3	777.	1.32	61%	.81
	4219.5	5016.3	796.8	1441.5	1.8		1.088
	4939.4	5901.	961.6	1470.	1.52		.93
	5901.	7040.5	1139.5	1745.8	1.53		.93
	7040.5	8500.	1459.5	1710.	1.18		.72
	8500.	9486.	986.	1946.6	1.97		1.20
	9486.	10257.6	771.6	1710.	2.2		1.34
30	1056.	1220.	164.	426.1	2.55	42%	1.07
	1220.	1449.	229.	465.	2.00		.84
	1449.	1620.4	171.4	646.5	3.8		1.60
	1620.4	1976.3	355.9	1059.1	2.97		1.25
	1976.3	2735.	758.7	1783.1	2.35		.99
	3283.8	3915.5	631.7	1343.	2.13		.89

those that have just been discussed we have weighed the feed employed. These feed records have been carefully culled and rejected wherever we have felt the data might be unreliable. In table 3 we have summarized typical portions of reliable data. All diets have been calculated to a dry basis. These data show that trout require from 1.1 to 3.8 units of dry feed to produce one unit increase of body weight. These data have only been calculated for the growing period since the spawning season may even show a loss of weight so the feed consumed is not quite sufficient for maintenance. Due to the slower rate of growth one might guess that the trout would be a less efficient converter of matter than the more rapidly growing of the higher mammals such as swine. Such is not the case, however, because it takes about four pounds of dry feed to produce a pound of pork while it takes considerably less than this to yield a pound of trout.

In all nutrition experiments we are concerned not only with the growth of the trout but also in its condition at sexual maturity and whether or not it can produce normal eggs.

In our previous annual report (2) we stated that "Trout reared upon combinations of raw meat and dry skim milk attain a normal sexual maturity and produce normal eggs." After this report had gone to press it was found that a large number of these eggs failed to hatch. As this might have been caused by any one of several factors, the question is in doubt and the statement is withdrawn.

Section II

THE RELATION OF COOKED STARCH, RAW STARCH, ROUGHAGE AND VITAMINS TO THE GROWTH OF BROOK TROUT

In a previous report (3) we have shown that such cereal products as wheat flour, corn gluten and peanut meal are used by trout for growth probably as a source of energy. Since these products were fed without cooking and since it is known that starch is better utilized by some of the higher mammals such as the rat and man if it has been cooked, we have designed diets Nos. 37, 38, 39 shown in table 4. In this same table we have shown the composition of diets 40, 41 and 42 which were designed to determine whether the growth rate was checked by including in the diet varying amounts of cellulose. We had already found that the growth of the rat is decreased considerably by placing either ten or twenty per cent of cellophane, a form of cellulose, in the diet (4). Since the trout has a shorter intestine than the rat we might expect it to suffer more severely. Diets 43 and 44 which are also shown in table 4 were included to afford additional evidence that Factor H is an entity different from any of the recognized vitamins. Number 43 contained vitavose to supplement the vitamin B that is already present

TABLE 4

Diet No.	Fish Meal	Raw Liver	Cooked Starch	Raw Starch	Dextrin	Cello-phane	Cod liver oil	Vitavos
37	29	21	50	..	..	..	..	..
38	29	21	..	50	..	..	..	..
39	29	21	..	..	50	..	..	..
40	29	21	..	..	45	5	..	..
41	29	21	..	..	40	10	..	..
42	29	21	..	..	30	20	..	..
43	14	..	..	..	76	..	5	5
44	10	21	..	..	69	..	..	..

TABLE 5

Diet No.	Alive beginning	Alive after 32 weeks
37	30	29
38	30	9
39	30	19
40	30	28
41	30	29
42	30	28
43	30	4
44	30	26

in fish meal. Cod liver oil was also included in this diet in an amount adequate to provide vitamins A and D. Both diets 43 and 44 were designed to contain about ten per cent protein since this is the minimum that permits growth in an animal such as the rat.

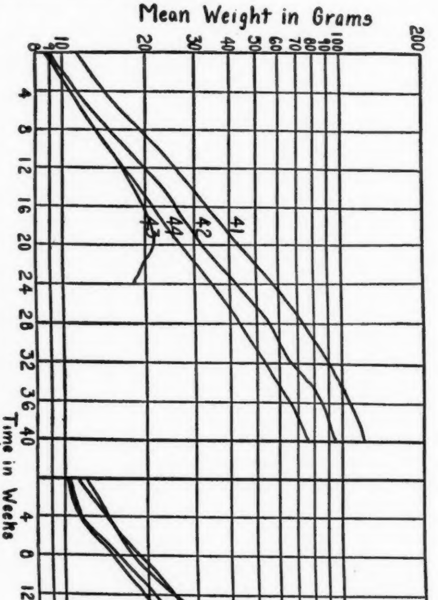

Chart 2. Curves 37, 38 and 39 show growth rates upon diets containing large amounts of raw starch, cooked starch and dextrin respectively. Groups 40, 41 and 42 were fed diets containing 5, 10 and 20 percent cellophane without any injury to their growth and with very low mortality rates. Groups 43 and 44 were both fed low protein rations. 43 was fed a rich supply of vitamins A, B and D and failed. 44 received its vitamins as raw liver and succeeded.

These experiments were carried out during a forty-week period. The growth curves for the average individuals upon the various diets are shown in chart 2. The mortality rates are shown in table 5. From chart 2 and table 5 one can draw the following conclusions:

(1) Dextrin is better utilized by the trout than cooked starch.
(2) Cooked starch is much better utilized than raw starch.
(3) Trout are not stunted by a comparatively high level of cellulose in contrast to the rat.
(4) Roughage seems to have a beneficial influence when included in the trout ration since it produces a decreased mortality.
(5) The limiting factor in dry feeds for trout is none of the recognized vitamins but some unknown substance contained in raw meat which we have termed "factor H". (Contrast curves and diets 43 and 44.)
(6) If other factors are satisfactory trout can attain an almost normal growth rate upon a protein level as low as ten per cent. This contrasts with our earlier results where factor H was absent and the trout was stunted on a ten per cent casein diet.
(7) No. 43 failed because of the absence of beef liver and shows that ordinary fish meal lacks factor H.

We have no explanation to offer for the difference in the reactions of the growing rat and trout to high roughage diets other than the possibility of the rapid passage of food through the intestine of the trout and its slow passage through the rat. This might permit the trout to consume ample amounts of essential nutrients for growth and maintenance while the rat suffers from partial starvation. Since the starch utilization has been improved by cooking we will be obliged to repeat a number of our earlier experiments with cereal products in which we must determine the influence of cooking upon the entire cereal.

Section III

THE RELATIVE VALUES OF SOYBEAN, COCOANUT, COTTONSEED AND LINSEED MEALS AS TROUT FEEDS

Among the common stock feeds used in rearing farm animals, soybeans, cocoanut, cottonseed and linseed meals are widely used. Cottonseed meal would be more widely employed except that it is quite toxic to certain species of growing animals. This toxicity varies widely with both the district that has produced the cottonseed and the process by which it has been treated as it is converted to meal. Linseed meal is quite highly prized in feeding farm animals since it seems to improve their physical appearance. However, Brioux and Richart (5) have recently analyzed a series of linseed meals and shown that they may contain quite large amounts of hydrocyanic acid which is toxic to young calves. Boiling the linseed cake removes the acid and it becomes harmless. In a series of studies upon trout, Almy and Richardson (6) found linseed meal to be quite toxic. They thought this toxicity was due to the hydrocyanic acid set free during digestion. To test the relative values of these products we have designed the diets shown in table 6. These were calculated to contain equal amounts of protein.

Table 6

No. 56		No. 57	
Cottonseed meal	25	Linseed meal	25
Raw beef liver	30	Raw liver	30
Salt mixture	3	Salt mixture	3
Dextrin	40	Dextrin	40
Cod liver oil	2	Cod liver oil	2
No. 58		**No. 59**	
Cocoanut meal	43	Soybean meal	21
Raw liver	30	Raw liver	30
Salt mixture	3	Salt mixture	3
Dextrin	22	Dextrin	44
Cod liver oil	2	Cod liver oil	2

The salt mixture consisted of one part sodium chloride, one part calcium carbonate and one part bone meal.

The growth rates upon these rations are shown in chart 3. These cover a period of twenty-four weeks and are still in progress.

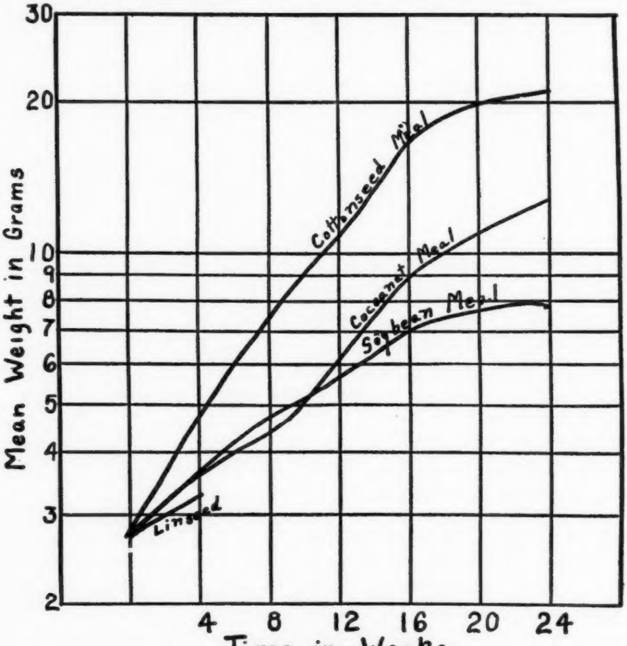

Chart 3. Growth curves showing the relative values of cottonseed, cocoanut, soybean and linseed meals when supplemented with raw liver.

All the trout upon the linseed meal ration grew slightly but died at the end of four weeks. This confirms the conclusions of Almy and Richardson since we have shown previously that trout can exist for several months with no food. The second reason for believing the linseed meal was toxic is that it caused trout to lose their equilibrium after it had been eaten. In contrast to the linseed meal ration there was no mortality upon either the cocoanut or cottonseed meal rations. Moderate growth resulted from the cocoanut meal and excellent growth from the cottonseed diet. The mortality upon the soybean meal ration was high and the growth rate poor. Although we made no attempt to secure an unusual grade of cottonseed meal, we should advise prospective users of this product to purchase it in quite large quantities and to feed a small test group with a representative sample before it is fed to large numbers of trout. Buying in large amounts will reduce the cost and frequency of testing. Cottonseed meal must be ranked with, red dog flour and peanut meal as among the very promising dry feeds that are available to the fish culturist in large quantities.

The Relative Value of Different Meats for Rearing Trout

In a previous report we have emphasized the importance of extended experiments to develop reliable data for practical application (2). We have shown that experiments covering short periods yield inconclusive results unless either very large groups such as those of Dr. Davis (7) or Mr. Bing (8) are employed or unless there is an immediate and marked failure upon a given diet. In our preliminary report (2) we have shown the growth curves upon a series of meat diets over a period of twenty-eight weeks. These experiments were not terminated, however, until the end of the fiftieth week. In table 7 we have presented a final summary of these results.

Table 7

Diet Composition		Mean Weight at Beginning. Grams	Mean Weight at End of Fifty Weeks. Grams
Beef liver		1	50
Beef liver Dry Skim Milk	80 20	1	58
Beef liver Cod liver meal	90 10	1	54
Beef liver Cod liver meal	90 10	1	46
Pork liver		1	45
Pork liver Dry skim milk	80 20	1	44

Table 7 (*Cont.*)

Diet Composition		Mean Weight at Beginning. Grams	Mean Weight at End of Fifty Weeks. Grams
Pork liver	90		
Cod liver meal	10	1	51
Beef Melts	80		
Dry skim milk	20	1	45
Beef liver	80		
Dry skim milk	15		
Cod liver meal	5	1	66

All diets were supplemented with 0.75% of calcium carbonate. From these data we can add little to our previous conclusions, namely that dry skim milk is a more effective supplement for beef liver than for pork liver, that pork liver is slightly inferior to beef liver, that cod liver meal has only a nominal value but might have a distinct value as a source of iodine for the prevention of thyroid tumor. All these rations are quite satisfactory and the one selected for practical use would be the cheapest in the cost of original materials and the labor of feeding. Since only two fish died out of the five hundred which were carried upon these diets for fifty weeks we have given no mortality data.

A second series of practical meat diets have been started. A preliminary report can be made. The compositions are shown in table 8.

Table 8

Diet Number	Composition
60	Dry Haddock 25 Mixed raw meats 75
61	Dry Haddock 50 Mixed raw meats 25
62	Dry Haddock 75 Mixed raw meats 25
63	Beef spleen
64	Beef spleen 80 Dry skim milk 20
65	Pig liver
66	Pig liver 80 Dry skim milk 20
67	Beef spleen 50 Peanut meal 25 Dry skim milk 25
68	Lungs
69	Lungs 65 Dry skim milk 33 Cod liver oil 2

The dry haddock used in numbers sixty to sixty-two represents the residues after the fillets have been cut from the sides. The remaining product is then dried. In such diets as number 67 water was added until a satisfactory physical composition was obtained.

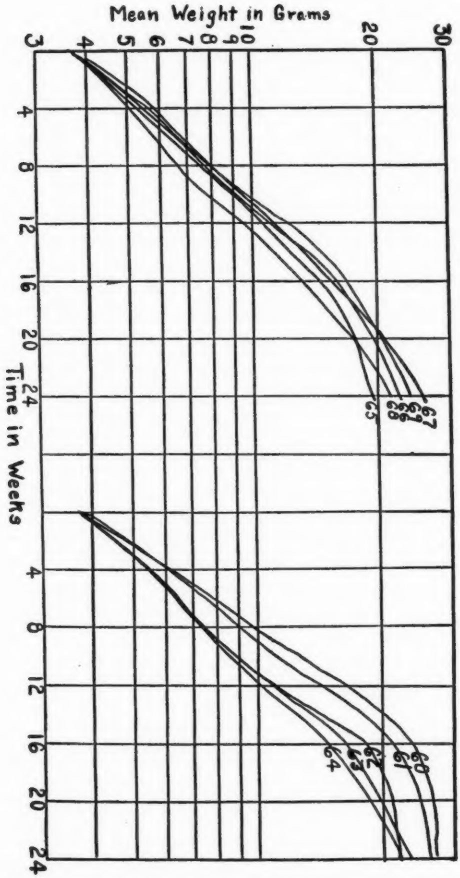

Chart 4. Growth curves showing the relative value of beef liver, pork liver and melts alone and when supplemented with dry feeds such as skim milk.

The growth curves upon these diets are shown in chart 4. The results are so nearly alike that one can draw no conclusions after a period of six months. These data indicate, however, that the dry haddock waste is a very satisfactory dry feed even when fed at relatively high levels. Since raw meat is about three-fourths water, the percentage of haddock

fed when calculated on a dry basis is about fifty in diet 60, about seventy-five in diet 61 and about ninety-two in diet 62. Since diet 67 when calculated to a dry basis is also composed of three-fourths dry feeds and since this diet has also given excellent results during this period one has another patent illustration of the waste of money in the many hatcheries that forget that the cost of raw meat must be multiplied by four to compare it with dry commercial feeds.

Another interesting development in these preliminary results is the good growth obtained from feeding lungs alone. This is probably a greater surprise to students of nutrition than to the practical fish culturist, however. The results with diet 67 confirm our earlier experiments which showed that both peanut meal and dry skim milk are satisfactory dry feeds for trout when fed with raw meat.

Experiments in Using the Raw Wastes From Sea Fish in the Rearing of Trout

Since the value of sea fish in both human and animal nutrition is well established, we have been interested for some time in the possibilities of the use of sea fish wastes for the rearing of trout. In table 9 we have shown the composition of a series of rations in which we employed raw fish products. This table shows the mortality in the course of forty weeks. The experiment started with 50 in each group.

Table 9

Diet Number	Number alive 40th week	Composition
1	41	Haddock flesh
2	0	Haddock flesh 90 Fresh cod livers 10
3	50	Haddock flesh 75 Fresh beef liver 25
4	46	Whole cleaned haddock wastes after the removal of the filets.
5	16	Diet four 90 Fresh cod livers 10
6	48	Diet four 75 Fresh beef liver 25
7	0	Whole ground herring.
8	50	Haddock flesh 66 Dry skim milk 34
9	48	Haddock flesh 50 Wheat flour 50
C	50	Raw beef liver.

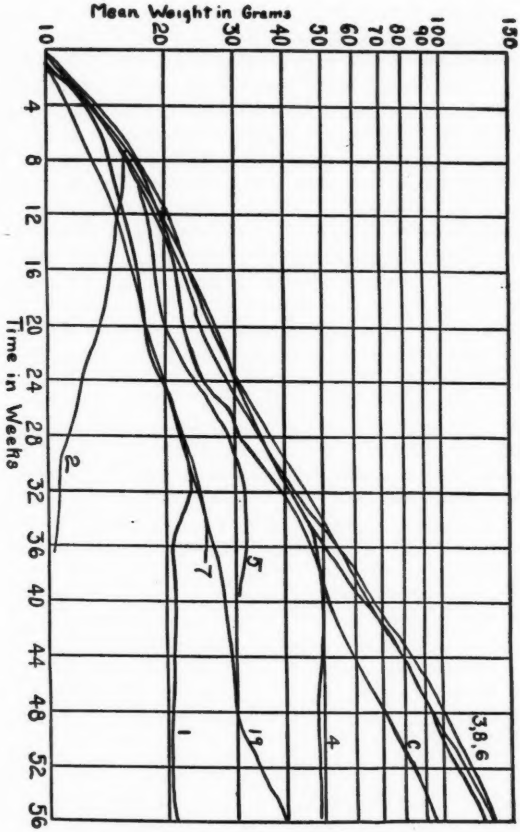

Chart 5. Growth curves for a period of a year upon raw haddock alone and supplemented. Curves 3, 8 and 6 show the excellent results obtained with raw haddock supplemented with such products as dry skim milk or beef liver. Curve C shows the mixed meat diet used in the hatchery. Curve 4 shows the results with haddock alone.

These diets were fed to individual groups for a period of 56 weeks. The growth curves are shown graphically in chart 5. At the beginning of this experiment each group contained fifty fish. All groups suffered from a considerable mortality except numbers 3, 8 and C. The diets

of Nos. 2, 5, and 7 had all proved very unsatisfactory by the end of the thirtieth week. The members of these groups became heavily infected with parasites and died. This illustrates a long debated point, namely that part of the disease found in hatcheries is the result of faulty diet. Such failures can not be attributed to one constituent of the ration but rather to the fact that the given diet is incomplete and must be supplemented with such substances as minerals, vitamins, etc. We obtain a failure upon haddock flesh alone but an excellent result when we supplement this same haddock flesh with dry skim milk as in diet 8 of table 9. Our groups upon satisfactory diets altho exposed to these same infections in adjoining tanks were not afflicted. We have no explanation for either the failures upon whole herring or upon the diets containing cod livers. The former might have been due to the mechanical injury from herring bones altho this is not likely. The results with raw cod livers are the opposite from what one might have guessed. Haddock flesh when supplemented with either beef liver or dry skim milk proved a more satisfactory diet than the usual mixed meats from the hatchery. The fact that both dry skim milk and raw beef liver proved satisfactory is of special interest since we have shown previously that dry skim milk alone is an excellent food for growth promotion for about fourteen weeks after which the trout die suddenly. Since we have found that both beef liver and raw haddock flesh form a complete trout food when combined with dry skim milk we must conclude that they both contain the unknown factor we have termed "H".

Since both haddock flesh, diet 1, and haddock waste, diet 4, failed when not supplemented and succeeded when supplemented with either raw beef liver or dry skim milk one may well assume that factor H is present in the haddock but that the failure of haddock alone must be attributed to some factors such as the vitamin B fractions which are known to exist in both dry skim milk and raw liver but to be relatively low in haddock flesh (9).

Table 10

Diet Number	Number alive after 23 weeks	Composition
47	12	Dry haddock 15 Dextrin 85
48	42	Dry haddock 30 Dextrin 70
49	26	Dry haddock 50 Dextrin 50
50	43	Dry haddock 80 Dextrin 20
51	28	Dry haddock 100
52	49	Dry haddock 50 Dextrin 40 Yeast 5 Cod liver oil 5

Since diet 4 proved satisfactory over a considerable period of time we designed the diets shown in table 10 in order to test this same haddock

waste after it was dried. These experiments were designed for drastic tests with no intention of using such for practical feeding since we had already shown that even raw haddock must be supplemented for practical use. This table also shows the mortality rates.

Dry Haddock as distinguished from ordinary commercial fish meal, used in these experiments, was especially prepared and furnished by the General Foods Company, Gloucester, Mass.

Dextrin was used as a source of calories in all these diets since the earlier experiments had shown it can be used by the trout. It has a special value in experiments of this type since it acts as a binder for the diet. Fifty individuals were originally included in each group. The growth curves for a period of sixteen weeks are shown in chart 6. The number of fish alive at the end of twenty-three weeks is shown in table 10.

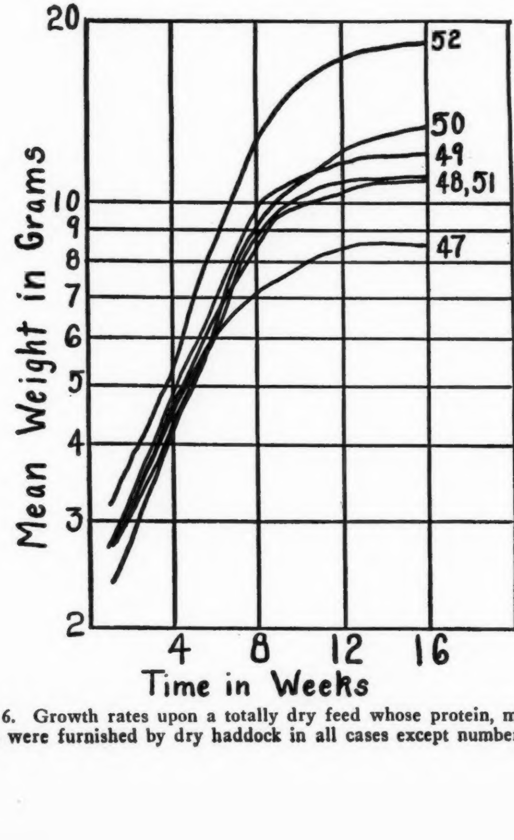

Chart 6. Growth rates upon a totally dry feed whose protein, minerals and vitamins were furnished by dry haddock in all cases except number 52.

These data show the following points:

(1) For a period of eight weeks these groups with the exception of the low protein one, number 47, have shown a growth rate that equals the best we have ever obtained. This is shown clearly by comparison of charts 4 and 6.

(2) Since group 47 shows the least growth and the highest mortality this is undoubtedly too low, probably in protein and vitamins.

(3) Since diet 52 which was similar in composition to 49 has shown both the lowest mortality and the best growth we have the first evidence we have ever been able to obtain that trout require some of the factors contained in yeast and cod liver oil. This does not change our earlier stand that money spent for these substances to augment the usual hatchery diet of raw meats is wasted. We shall maintain this position until someone shows that there is a positive value in adding these to a practical hatchery diet.

(4) Diet 52 has proved to be the best dry feed we have found thus far. In our previous attempts we have had the most success with such substances as dry skim milk and cod liver oil or dry skim milk and dried liver. With these diets, we reared trout from a weight of three or four grams to one of ten grams in the course of fifteen weeks, with a mortality of 50-75 per cent at the end of this period. In the case of diet 52 we have reared them to an average weight of nearly twenty grams at the end of fifteen weeks with only a two per cent mortality at the end of twenty weeks at the time of preparation of this report. Since this group has been studied for only twenty weeks and since only one group has been used in the experiment we are not at all certain that diet 52 will prove to be a nutritionally complete dry feed for brook trout when fed over an extended period. Further experiments will be conducted to determine this point.

SUMMARY

The growth curves for brook trout fed under optimum conditions for a period of two years have been obtained.

Our work to show the growth rate after a period of stunting confirms our earlier conclusion that there is a real acceleration.

Data upon the efficiency of the trout as a converter of matter show this species to be more efficient than the higher warm blooded animals such as swine.

From growth data it has been found that trout use cooked starch and dextrin much better than raw starch as a source of energy.

In contrast to the rat the trout is not affected in its growth by relatively high levels of cellulose. Moderate amounts of cellulose to act as roughage seem to have a positive action in the promotion of physical well being.

Further evidence is given for the existence of factor H as a separate entity from the other vitamins.

Soybean, cocoanut, cottonseed and linseed meals have been fed with equal protein intakes and their relative values determined by the biological method. The work of others showing linseed meal to be very toxic has been confirmed. Soybean meal was poorly utilized; cocoanut meal proved of moderate value; cottonseed meal proved to be thoroughly utilized for growth.

A new series of comparative studies upon the relative values of different meats commonly used in the hatchery for rearing trout has shown that fresh lungs alone are adequate for growth over a considerable period. Peanut meal and dry skim milk form a very effective combination with raw meats.

An extensive series of studies has been carried out upon various wastes from sea fish, chiefly haddock. Haddock wastes both raw and dried seem very promising material for extensive use by the fish culturist.

In the course of a series of experiments with dried haddock residues we have secured excellent growth for periods of three to four months. This same series of experiments has afforded us the first evidence that brook trout have some need for one or more of the accessory factors in yeast or cod liver oil.

We wish to thank Prof. L. A. Maynard, Prof. G. C. Embody and Dr. Chester Tolle who have offered many worthwhile suggestions during the progress of this work.

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XIII. Discussion

MR. W. T. THOMPSON: It is difficult for me as a practical man to appreciate any statement to the effect that alternately feeding and starving will improve trout.

MR. EBEN W. COBB (Connecticut): I think Mr. Thompson is laboring under a misapprehension as to the meaning of this experiment. There is no intention to maintain that starving improves a fish, but the experiment does show that fish are able to withstand periods of starvation and still under a proper environment remain in fair condition.

I would like to describe briefly some experiments now being conducted which show the more practical use of some of these foods. We are endeavoring to determine the comparative values of the different meats and their value in our mixed feed. An experiment with single food, although readily eaten, does not necessarily prove that the fish would not do better if the two foods were mixed.

When dry foods have been found to have some value we try to determine the percentage at which this value can best be used, and also the most practical method of administering this food economically. We have found that in the case of some food combinations which are apparently not particularly good, a mixture of a small amount of meat will considerably enhance their value. We are trying now to find whether the same amount of meat which has been given constantly can be administered at varying periods and still produce the same result. For instance, we are feeding 15,000 fingerling fish with a mixture of dried milk and fish meal with an additional fifty pounds of sheep plucks one day a week. We have found so far that the best way to administer dry food with the meat is to mix it with the meat to about ten per cent. We can readily mix any of these products by running them with the meat through the meat cutter up to this amount. Of course when we mix our milk and fish meal together we have to moisten it so that it crumbles readily. By pressing it solidly into a cake it can be broken up; there is very little waste and the fish take it readily. The 15,000 fingerlings take ten pounds of milk and fish meal, dry weight, per day, which I think is quite sufficient food for that number.

The fish will take dried buttermilk, cracked wheat size, without mixing with meat. It is simply moistened and thrown in the trough, where the fish will take it nicely. This food could be used where meat was not available. Clam meal is simply clam heads ground into small form for the smaller fish. For fingerlings of three inches the clam heads moistened with water and put through the cutter with the meat are as good as clam meal. Concentrated sour milk contains about seventy-five per cent moisture. At three and a half cents a pound it is more expensive that the dry milk at eight and a half. We are at present feeding clam heads, buttermilk and fish meal as part of our regular diet.

Dr. A. H. Wiebe (Iowa): It might be interesting in this connection to mention some work recently published in Szecho-Slovakia. Dr. Langhans experimented with the growth of carp, not by limiting their food supply but by limiting their space. These carp were confined in small quarters for five years, with plenty of available food at all times, yet they remained small. At the end of five years he gave them ample room as well as ample food, and within the short space of three months these fish gained enormously in weight, whereas the controls in the small aquarium gained but slightly.

Thirty or forty years ago Professor H. S. Colton of the University of Pennsylvania was interested in rearing snails in aquaria. He found that if he starved a particular snail and then after a certain number of days gave it food, it would gain materially in weight, and that at the end of thirty-five or

forty days the starved snail would exceed in weight the control which had been fed continuously. He also found that the growth of the snails was inhibited by the accumulation of excretory material and by exposure to unfavorable temperatures; but that adversity had somehow affected the animal so that if placed in a favorable environment it soon overcame all its shortcomings.

MR. P. VIOSCA (Louisiana): One of the most important features of this paper was the reference to the use of cellulose as refuse for carnivorous species. The artificial diet of trout does not provide the refuse that the trout would have on a natural diet. For instance, the trout takes its food whole in nature, and the more or less indigestible hair, feathers or coverings of insects act as refuse for these carnivorous species. If the trout were given under artificial conditions something which approaches their food under natural conditions it might prove advantageous.

THE FOOD OF THE TROUT IN MICHIGAN

By Dr. Jan Metzelaar

An investigation of the feeding habits of the trout in Michigan was undertaken in 1927. Jars of diluted formaldehyde with tags attached were distributed throughout the State with the request that the fishing public save and preserve the stomachs of rainbow trout for later examination. The hearty response of the public resulted in 451 preserved stomachs being returned.

During 1928, 1500 jars with brook, brown and rainbow trout tags attached were distributed among the fishermen of the State with the request that trout stomachs be saved. Each stomach was to be preserved separately and on the attached labels was entered the following information: Length of trout, date of capture, name of fisherman and name of water from which taken. Different colored labels are used for each species of trout.

The public co-operated splendidly and returns were made by eighty-nine people who contributed nearly seven hundred trout stomachs. A small number were not used on account of improper markings on jar labels but 649 jars of stomachs were received as follows:

Brook trout	411
Brown trout	191
Rainbow trout	47

The contents of each stomach were sorted, measured and classified under the following seven headings:

Land insects, comprising all arthropod animals taken by the trout from the air. The large majority are winged insects with a few caterpillars, spiders, centipedes, etc.

Water insects, both larval and adult, taken obviously under water as belonging to the aquatic fauna proper.

Fish, including a few pieces apparently used as bait.

Crustacea, comprising mostly crayfish with a few scattered amphipods (shrimp or scuds.)

Vegetation, comprising almost exclusively filamentous green algae.

Mollusks, comprising snails and small clams.

Trash, comprising anything indigestible, such as gravel, wood, paper and other debris.

The measuring of each constituent was undertaken by water replacement. At the end of the analysis the individual records for each stomach were arranged according to size of trout and again according to month of capture. In Tables I-III are found the percentage of each kind of food eaten by trout of different sizes. All of the 1927 rainbow data, covering a total of a thousand stomachs, has been incorporated in this report.

Discussion

As shown by Tables I-III and further illustrated by the graphs, all trout are characterized by an unmistakable decrease of insects in the diet and an equally sharp increase of crustacea and fish as the size of the trout increases. This feature is the most pronounced in rainbow and also in browns, probably because these species grow to a larger size than brook trout in which the percentage of fish appears rather uniform throughout the range (about 20%).

Brown trout up to 9 inches long appear to be harmless insect feeders (ration 84%), but as they grow larger they distinctly turn to a crab and fish diet and end their career as predaceous fish, living almost entirely (70%) on a fish diet.

Rainbow trout have not yielded any essentially new data, but the 1927 and 1928 records have been combined and re-tabulated in the same way as those of the other species. The outstanding feature of the rainbow diet certainly is the 15% vegetation, formed largely by filamentous green algae. These algae are found both in the stomach and in the intestine proper in a half digested condition. For appreciation of this fact we have to turn to Table VI, which shows the seasonal distribution of the food. This table shows a sharp increase of algae consumed in the month of August. At that time, algae becoming very abundant in some of our larger trout streams, begin to drift down and constitute more than one-fifth of the food of rainbow trout. Algae must be regarded as one of the factors contributing to the success of the rainbows in streams like the Pere Marquette River and others.

Inasmuch as no algae have been found in any of the 600 stomachs of brook or brown trout the theory is ventured that rainbows are in a better position to utilize the food supply of a stream than either of the other species.

Conclusion

The findings on the kind of food preferred by different sizes of our three kinds of trout bear out the experience of our fishermen in that bait catches the larger trout while flies catch the smaller ones. It also tends to show that a small fish is a better bait than a worm.

Basis of Comparison.—The stomachs of the three kinds of trout used in the present investigation were not all collected in the same streams and therefore the criticism may be offered that there is no uniform basis for comparison between these three species.

In order to meet this objection, all the streams from which our trout were taken have been tabulated in Table V on a percentage basis. It will be seen at a glance that very few came from the Upper Peninsula, but practically all from the northern half of the Lower Peninsula of Michigan, more particularly from the region with heavy, sandy glacial deposits. We think the ecological conditions prevailing in the trout streams of this general region are uniform enough to serve as a basis of comparison between the three species. Furthermore, the Au Sable system, our most important trout stream, yielded about 30% of the stomachs of all three species of trout.

Fish Eaten by Trout.—Special attention has been given to the fish item in the trout diets. The fish remains have, as far as possible, been determined jointly with Dr. Carl L. Hubbs, Curator of Fishes of the Museum of Zoology, Ann Arbor, Michigan, to whom thanks are due for his invaluable assistance.

Table IV gives a summary of percentages and total quantities of fish eaten by the three different species of trout. The results are very suggestive:

1. Neither brook nor brown trout are found to participate in the rush on fresh rainbow eggs in the spring months like the medium-sized rainbows who follow the schools of the large spawners. Investigations thus far tend to show rainbow trout eat the eggs of their own species during the spawning season.

2. Muddlers form the most important fish food for the trout in our streams.

3. In contrast with brook trout, brown trout feed on young trout to a considerable extent. The contrast between the three species in this respect, as illustrated by Table IV, is very striking inded.

4. Brown trout alone appear to feed on lamprey eels. This fact has for some time been claimed by sportsmen but is now borne out by actual investigation. This is of interest because parasitical lampreys are undesirable in trout streams and non-parasitical ones are at least not beneficial, inasmuch as they die after spawning, often in surprisingly large numbers.

Seasonal Distribution.—In Table VI, an attempt is made to analyze the kind of food preferred by trout in each of the four months of the trout season in Michigan. It shows, for instance, a sharp increase in the percentage of land insects taken during June and July for brown trout, compensated by fish and crustacea in May and August. It would also be very interesting to analyze the average volume of food ingested by adult trout in the different months of the year as it may be expected that large trout show a more marked seasonal variation in their feeding habits, both as to quantity and diet, with special reference to the season of spawning. Table VI probably does not indicate the true condition due to the inclusion of an abundance of small and medium-size trout which are primarily insect feeders. To establish these relations definitely we need more material from large trout.

TABLE I
PERCENTAGES OF VARIOUS FOODS CONSUMED
BY
BROOK TROUT OF DIFFERENT LENGTHS
1928

Lengths of trout in inches	7-9	9-11	11-13	13-17	Average for all size classes
Aquatic Insects	40.7%	31.4%	37.8%	16.7%	33.9%
Land Insects	32.3%	17.1%	8.5%	10.4%	20.4%
Fish	12.1%	31.8%	12.4%	11.4%	20.5%
Crustacea	5.7%	11.8%	15.6%	60.3%	15.1%
Mollusks	2.1%	1.8%	1.1%	0.5%	1.9%
Worms	2.4%	1.9%	20.5%	...	4.3%
Trash (indigestible)	4.7%	4.2%	4.1%	0.7%	3.9%
Number of trout in each class	165	169	43	17	394
Total quantity of food, consumed in each size class (c.c.)	139.3	175.6	53.2	41.3	409.4

Note: In this table only such trout are entered of which individual length records are available.

TABLE II
PERCENTAGES OF VARIOUS FOODS CONSUMED
BY
BROWN TROUT OF DIFFERENT LENGTHS
1928

Lengths of trout in inches	7-9	9-11	11-13	13-15	15-17	17-22	Average for all size classes
Aquatic Insects	62.7%	39.1%	44.4%	43.3%	12.0%	21.8%	36.9%
Land Insects	21.3%	21.1%	27.1%	15.7%	3.0%	0.3%	15.6%
Vertebrates (Fish & 1 Mouse)	1.8%	13.4%	10.3%	2.8%	44.6%	53.7%	18.8%
Crustacea	0.9%	6.4%	9.1%	33.2%	23.7%	20.3%	17.9%
Mollusks	6.2%	2.9%	2.9%	0.5%	8.3%	1.6%	2.7%
Worms	0.4%	10.5%	0.8%	0.7%	1.4%	..	..
Trash (indigestible)	6.7%	6.6%	5.4%	3.8%	7.0%	2.3%	5.0%
Number of trout in each class	30	57	52	32	11	9	191
Total quantity of food, consumed in each size class (c.c.)	22.5	108.0	74.7	121.2	43.4	68.9	438.7

Note: In this table only such trout are entered of which individual length records are available.

TABLE III
PERCENTAGES OF VARIOUS FOODS CONSUMED BY RAINBOW TROUT OF DIFFERENT LENGTHS
1927—1928

Lengths of trout in inches	7-9	9-11	11-13	13-15	15-17	17-22	22-30	Average for all size classes
Aquatic Insects	54.7%	33.3%	35.6%	30.7%	28.6%	1.2%	0.5%	25.1%
Land Insects	25.4%	19.6%	11.0%	9.2%	13.3%	0.9%	3.9%	11.5%
Fish	0.1%	8.9%	9.0%	3.9%	4.6%	15.5%	24.0%	10.1%
Crustacea	9.3%	6.4%	9.4%	25.4%	29.9%	56.0%	51.7%	28.3%
Vegetation	4.9%	19.3%	26.2%	19.9%	16.7%	19.3%	11.8%	16.6%
Mollusks	1.5%	1.5%	2.8%	8.8%	5.2%	2.4%	..	2.7%
Worms	0.3%	3.6%	1.0%	0.7%	..	2.0%	1.4%	1.4%
Trash (indigestible)	3.8%	7.4%	5.0%	1.4%	1.7%	2.7%	6.7%	4.3%
Number of trout in each class	125	87	68	51	25	27	12	395
Total quantity of food, consumed in each size class (c.c.)	158.6	134.8	155.4	98.5	108.7	187.7	155.7	999.4

Note: In this table only such trout are entered of which individual length records are available.

TABLE IV
PERCENTAGE OF DIFFERENT KINDS OF FISH CONSUMED BY TROUT
1927—1928

Name of Fish		Brook	Brown	Rainbow
Trout	(Salmonids)	...	44.4%	6.3%
Trout eggs	(of rainbow)	...	...	9.5%
Muddlers	(Cottus)	67.3%	34.7%	50.6%
Minnows	(Cyprinids)	22.1%	3.5%	7.4%
Perch	(Perca flavescens)	1.2%	..	..
Bass	(Aplites salmoides)	..	..	2.1%
Darters	(Etheostomids)	3.0%	11.5%	4.2%
Suckers	(Catostomids)	0.4%	..	13.3%
Lampreys	(Petromyzontids)	..	3.9%	..
Undeterminable fish		6.0%	2.0%	6.6%
Total quantity of fish food (in c.c.)		86.3	82.4	101.6
Percentage of total food contributed by fish		20.5%	18.8%	10.1%

TABLE V

PERCENTAGE OF TOTAL NUMBER OF TROUT STOMACHS SECURED FROM VARIOUS MICHIGAN STREAMS

Name of Stream System		Brook	Brown	Rainbow
UPPER PENINSULA				
Sault Rapids		..	..	0.4%
Chocolay River	(Marquette Co.)	..	..	0.2%
Dead River	(Marquette Co.)	0.5%	..	0.4%
Sucker River	(Alger Co.)	2.2%	..	..
Au Train River		0.5%	..	..
LOWER PENINSULA				
Sturgeon River	(Cheboygan Co.)	1.5%	..	3.2%
Pigeon River	(Cheboygan Co.)	6.6%	..	2.8%
Black River		3.4%	..	..
Au Sable River		30.2%	30.2%	34.0%
Pine River	(Alcona Co.)	..	..	5.6%
Rifle River		..	..	2.6%
Au Gres River		..	..	1.0%
Cedar River	(Gladwin Co.)	..	..	3.2%
Manistee River		26.5%	1.2%	9.0%
Little Manistee River		14.1%	1.7%	4.0%
Sauble River	(Lake & Mason Co.)	2.9%	1.7%	2.4%
Pere Marquette River		3.2%	64.0%	24.0%
White River		1.4%	..	..
Cedar Creek	(Oceana Co.)	2.4%	..	..
Muskegon River		3.6%	1.2%	3.0%
Stray Specimens		1.0%	..	4.0%
Total number of stomachs		411	172	498

Note: In this table only such stomachs are entered, for which locality records are available.

TABLE VI

MONTHLY PERCENTAGE OF VARIOUS FOODS CONSUMED BY BROOK, BROWN & RAINBOW TROUT

(Based on month totals)

		May	June	July	August
Aquatic Insects	Brook	46.0%	40.0%	23.9%	23.8%
	Brown	23.4%	46.8%	48.6%	29.5%
	Rainbow	50.9%	29.3%	33.3%	9.1%
Land Insects	Brook	11.8%	20.8%	25.4%	21.9%
	Brown	3.0%	25.2%	23.8%	31.4%
	Rainbow	9.5%	8.9%	20.7%	25.3%
Fish*	Brook	15.8%	16.0%	21.1%	31.7%
	Brown	35.4%	3.1%	6.1%	28.2%
	Rainbow	7.1%	14.5%	7.4%	6.3%
Crustacea	Brook	10.4%	14.6%	22.2%	14.5%
	Brown	28.1%	8.4%	16.2%	5.3%
	Rainbow	12.5%	27.7%	22.6%	26.7%

TABLE VI (*Continued*)

		May	June	July	August
Vegetation	Brook	...	...	...	...
	Brown	...	...	...	...
	Rainbow	2.3%	13.1%	8.2%	22.5%
Mollusks	Brook	2.0%	2.0%	0.6%	2.3%
	Brown	0.6%	6.4%	1.2%	2.5%
	Rainbow	9.3%	2.0%	3.1%	2.1%
Worms	Brook	10.0%	3.0%	2.8%	1.4%
	Brown	5.3%	2.0%	0.1%	...
	Rainbow	2.8%	0.6%	0.2%	1.3%
Trash (indigestible)	Brook	4.0%	3.6%	4.0%	4.4%
	Brown	4.2%	8.1%	4.0%	3.1%
	Rainbow	5.6%	3.9%	2.5%	6.7%
Total quantity of food consumed in c.c.	Brook	120.0	114.1	104.4	74.3
	Brown	159.4	93.2	98.4	31.9
	Rainbow	180.7	369.7	118.7	281.3

Note: Only properly dated records could be used in this table.

* This column includes one mouse, eaten by a brown trout in August.

XIV.—Discussion

Dr. Metzelaar: We have exclusively relied on the co-operation of the sportsmen of Michigan for furnishing the necessary material for this investigation. To this end, 1,800 half-pint labelled fruit jars with formalin were distributed among the sportsmen. The labels were of three colors, red for brook, blue for brown, and yellow for rainbow trout. The sportsmen were asked to put only one stomach in each jar, to mention the exact locality where the fish was caught, the length of the fish in inches, the data, the name and address of the fisherman. They were asked also to supply a strip of the skin of the fish. The response of the sportsmen has been excellent. The total number of specimens received was: brook trout, 411; brown trout, 151; rainbow trout, 395; a total of more than 1,100 stomachs, which furnish valuable material indeed for these studies. In other words, more than fifty per cent of the jars were returned with the proper data. I have the results tabulated here in six tables.

Mr. W. T. Thompson: In respect to the consumption of trout eggs, Dr. Metzelaar gives the brook trout and the loch leven a clean bill, but solely because his studies did not continue through the spawning season. The brook trout and the loch leven did not consume rainbow trout spawn in the spring because the rainbow trout ascended to the upper waters while the other trout are down below. They could not eat the eggs if they were not there.

SOME OBSERVATIONS ON CHIRONOMID LARVAE AND THEIR USEFULNESS AS FISH FOOD

M. S. Johnson
University of Minnesota

I. Introduction.

A. The aquatic biology program of the University of Minnesota.

One of the projects of the Minnesota Experiment Station is an investigation in aquatic biology, a study of the factors affecting the productiveness of lakes in fish and fish food. The general plan of this study has been to make first a preliminary physiographic survey of groups of lakes in different regions of the state, determining for each lake of the groups studied, the size, depth, and general character, as well as the temperature and dissolved oxygen and carbon dioxide content at different levels. On the basis of this preliminary survey, lakes more or less representative of different conditions are selected for biological study, with especial reference to their bottom fauna. The expectation is eventually to be able to correlate the physical conditions with the kind and abundance of food organisms, and these in turn with the fish life of the lakes.

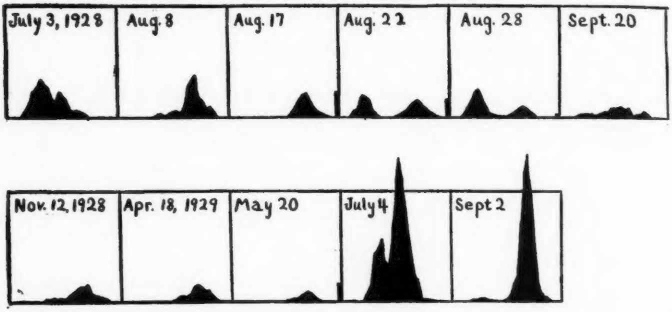
B. The midge situation at Lake Pepin—a serious nuisance.

In the spring of 1928 people living along the shores of Lake Pepin reported that flies coming out of the lake were so numerous as to be a very serious nuisance. I should say by way of explanation, that Lake Pepin is an expansion of the Mississippi River, it is about 20 miles long and about 2 miles wide, and is about 60 miles downstream from the Twin Cities. The flies which were causing annoyance were a large species of midge, *Chironomus plumosus*. These insects fortunately do not bite, but they occurred in such enormous numbers as to be almost intolerable. They alighted upon and defaced the walls and porches of houses; they crawled on and under one's clothes, and were crushed as people moved; they occasionally got into people's mouths, and some persons wore veils; the dead bodies of the midges accumulated in a windrow along the shore, and gave off an especially offensive odor as they decayed.

The stories that were told of the abundance of the insects had suggested mayflies, and it was something of a surprise to find that midges were responsible. Up to about ten years before, large mayflies had occurred commonly around this lake and the midges had not been noticed. With the appearance of the midges in numbers the mayflies had practically disappeared. The midges were considered much the more objectionable.

Because of the complaints, because the situation seemed an unusual and interesting one, and because it fitted neatly into the pro-

gram of investigation already outlined, Lake Pepin was selected for biological study with special reference to the midges. Some of the findings form the basis of the present paper.



Number, and length in mm. of chironomus plumosus larvae in bottom samples taken near Lake City Point, Lake Pepin.

II. Midge Larvae—size, number, and seasonal variation in Lake Pepin.

The greater part of Lake Pepin has a fairly uniform depth of about 30 feet. A portion of the upper end of the lake is shallower than this end and some of the lower end is deeper. The shore is gravel; the bottom, below the level of wave action, is mud. Bottom samples were taken with an Ekman dredge, each sample representing an area of 36 square inches of lake bottom. The mud was washed through a 20-mesh-to-the-inch sieve, and the organisms remaining in the sieve were sorted out and preserved. The most striking feature of the samples taken during July was the great and uniform abundance of chironomid larvae. Some of the samples showed these larvae at the rate of seven or eight thousand per square yard, and the estimated average for the entire lake bottom was around three thousand per square yard. The larvae were nearly all of the one species *Chironomus plumosus.* So far as I have been able to learn these figures far exceed any that have previously been reported for any considerable area of lake bottom below the vegetation zone. Samples taken from similar depths in several lakes near the Twin Cities showed relatively few chironomid larvae. The samples from Lake Pepin showed notable differences in August as compared to July, and in 1929 as compared to 1928. In August 1928 there was a general sharp reduction in number of larvae as compared with July. At a few sampling stations this reduction was hardly noticeable, but

in most cases it was extreme. This reduction in number of larvae corresponded with a period of emergence of adults. Toward the end of August some of the samples showed numbers of small larvae, progeny of the August swarm. Successive samples showed growth of the larvae, as well as changes in numbers. Larvae obtained in the first half of July 1928 were quite distinctly two size-groups, about 9 mm. and 14 mm. long respectively, evidently the progeny of the two swarms which had occurred earlier in the season—one the last half of May and the other the first half of June. A sample from the same station in July 1929 likewise shows two size-groups of larvae, about 11 mm. and 16 mm. respectively. There were practically no adult midges in evidence during July. In 1928 the larvae continued to grow to a size of 20-24 mm., and pupated and emerged during August, the larger size-group first. Before the end of August larvae of the new generation, 5 to 6 mm. long, were appearing in samples from some stations. A month later they averaged about 16 mm., and it had become evident that they were much less numerous than in the preceding generation. The adults developing from these larvae and emerging in May 1929 were less abundant than the swarms of the previous year. The larvae developing from eggs laid by the spring swarm in 1929 did not generally emerge in August, as had been the case the previous year. The reason for this difference in behavior in successive years has not been worked out. The accompanying graph shows the numbers and size of midge larvae in successive collections at one of the stations studied.

III. Midge Larvae as Fish Food

Studies of the food of fishes, by Forbes (1878-1888), by Pearse (1918-1921) and by others, show that insects, and especially insect larvae, constitute the most important portion of fish food. Of the insects used as fish food, the most important groups are the mayflies and midges. At Lake Pepin, with mayflies almost entirely absent and midges so extraordinarily abundant, it is to be expected that the midge larvae will form an unusually large proportion of the food of the fish there. Through the kindness of Mr. Zach Nihart, a commercial fisherman of Lake City, we obtained the insides of about two hundred fish from his catches, and preserved the contents of the digestive tracts. In addition we caught a few fish in gill-nets, and obtained the insides of a few other fish from anglers. All the fish included in this account were adults. Of the fish examined, the German carp (*Cyprinus carpio*), quillback (*Carpiodes cyprinus*), redhorse (*Moxostoma aureolum*) and channel cat (*Ictalurus punctatus*) ate chironomid larvae and pupae to the greatest extent.

Midge larvae or pupae, or the empty skins from which all digestible material had been extracted, were abundantly present in the

digestive tracts of these fishes, often to the exclusion of every other article of diet. A redhorse contained the remains of 2,350 larvae. A channel cat had eaten over 2,500 midge pupae. The only other fish in the lake, besides those listed above, which is of any considerable commercial value is the sheepshead. We did not find adult sheepshead feeding on midge larvae to as great an extent as the fish just mentioned, though Forbes reported that in Illinois half-grown individuals were insect eaters. However, there can be no question that, taken as a group, the commercial species of fish in Lake Pepin feed on midge larvae to a much greater extent than they have been reported as doing elsewhere.

IV. Midge Larvae and Fish Abundance

With midge larvae constituting, as they do, one of the more important classes of fish food, it is not unnatural to expect some relationship between the occurrence or abundance of midge larvae and the abundance of fish. That such a relationship exists has been demonstrated in the case of certain European lakes. Alm (1922) studying the bottom fauna and fish production of several Swedish lakes, classified the lakes on the basis of their bottom fauna. The lakes which he called the *Plumosus-type,* with bottom fauna consisting mainly of *Chironomus plumosus,* gave the greatest production of bottom fauna and the highest yields of fish. It is a fairly safe generalization that a good Chironomus lake is a good fish lake. Yet Lake Pepin affords a dismal exception to this rule. Although the food supply is extraordinarily abundant, the fish production is so low that fishing in the lake is now hardly worth while. As nearly as can be learned by inquiry, midges first began to be noticed in numbers around Lake Pepin about 1918. Following the appearance of the midges the commercial fish yield of the Lake increased until in 1922, if the published data are correct, it stood at the amazing figure of 145 pounds per acre for the entire lake. Such a catch would suggest that the lake was being overfished, except that a comparison with earlier statistics shows that the increase in fish was greater than the increase in men and equipment engaged in fishing. Since 1922, and more especially from 1924 on, the fishing in the lake has been very poor indeed although food is still present in abundance. I have considered various possibilities, but am inclined to attribute the scarcity of desirable fish to the great abundance of the short-nosed gar. This fish is not caught in the commercial nets. Some idea of its abundance may be had from the hauls of the fine-meshed nets of the U. S. Bureau of Fisheries. Ordinarily about one-third the bulk of such hauls consists of this one predacious species. The Fisheries crews are, or have been, required to return the gars safely to the water. Wagner (1908) reported this gar as seemingly rare in Lake Pepin.

Apparently it has increased since that time, following the increase of the fish upon which it feeds and favored by the fact that it is not affected by fishing operations, until it has finally become so abundant that it is keeping the more valuable fish far below the level of their available food supply. At any rate, and whether or not the abundance of the gar is the correct explanation, we have in Lake Pepin an instance of a lake in which midge larvae are exceptionally abundant, and the fish which feed on them were once also abundant but are now relatively scarce.

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XVI.—Discussion

Dr. A. H. Wiebe (Iowa): Was any difference observed in the abundance of midges in the upper and lower stretches of Lake Pepin?

Dr. Johnson: The uniform distribution and the abundance of these larvœ were astonishing. With one exception (in July when larvæ were in their greatest abundance) every sample from mud bottom showed an abundance of midge larvæ. Near the shore, at the entrance and outlet of the river, and on a few shoals, where the bottom was washed by wave action so that there was no mud, there were few or no chironomid larvæ. At one station, near the entrance of the river into the lake, where the bottom mud was particularly foul, I obtained a high count of pollutional annelids or sludge worms, and not a single chironomid larvæ.

Mr. Langlois (Michigan): I should like to inquire whether a comparison of the physiochemical conditions for the two seasons show any material difference, and if there can be shown any correlation between those conditions and the relative abundance of midge larvæ the second year.

Dr. Johnson: I regret that I am not able to answer the question. A year ago I thought I had worked out the life history of the species. Therefore my program for this summer did not include a continuance of this study. There

was nothing in the July sample to suggest that there would be an August swarm. The larvæ were more advanced in size than they had been the previous year, so I took no other samples until September 2nd, at which time I was surprised to find that most of the larvæ were still there instead of having emerged in August. I cannot believe that the lake is any colder than last year, which is supposed to be the reason for delayed emergence.

MR. LANGLOIS: May I ask also whether an analysis of the stomach contents of the gar pike justified the statement that the gar pike were responsible for the depletion of the game fish?

DR. JOHNSON: The gars are very abundant, and they have a reputation of eating nothing but fish. I have examined many stomachs. In all cases where there was anything at all in their stomachs it was fish, mostly small yellow perch.

MR. LANGLOIS: Therefore the apparent diminution may be attributed to the competition for food supply?

DR. JOHNSON: The predatory fish have not been reduced as much as the food fish. The northern pike is relatively abundant, and the wall-eyed pike is somewhat less.

MR. D. H. THOMPSON (Illinois): I would like to ask Dr. Johnson whether he regards large numbers of *Chironomus plumosus* as an indication that pollution is decreasing in Lake Pepin.

DR. JOHNSON: *Chironomus plumosus* is quite generally accepted as one of the best index organisms of pollution. Its status in this respect is based on an investigation by the Illinois Natural History Survey. I do not consider that pollution in Lake Pepin is particularly serious from the point of view of fish life because the reduction in the fish seems to have been general for all species, without any particular selection of the more sensitive fish. The red horse and suckers, which are generally classified as among the more sensitive fish, have been reduced no more in proportion than the carp, which is universally classified as a particularly hardy fish. In several Swedish lakes in which *Chironomus plumosus* was the dominant organism, not only the abundance of bottom fauna, but the productiveness of the lakes in fish was greater than in other types of lakes.

There is no data over a period of years which would indicate the trend of pollution in Lake Pepin. The State Board of Health of Minnesota, in co-operation with the Fish and Game Department and the Wisconsin Board of Health, has made an intensive study of the conditions of pollution in the Mississippi River. So we have a definite statement as to the amount of pollution in this section of the river system, but there are no previous data to use as a comparison. Lake Pepin, which formerly had a sand bottom, is now almost entirely a mud bottom lake, undoubtedly due to the influx of increasingly rich organic matter from the twin cities. On the whole it may be assumed, without definite and detailed information, that there is probably an increasing tendency towards pollution in the lake.

Mr. T. A. Olsen (Minnesota): We have not found that appearance of *Chironomus plumosus* is as important as some other organisms as an indication of pollution in the Mississippi River system. Probably *Chironomus plumosus* is a species which is sometimes found in zones between heavy pollution and clean waters. But I wish to correct the impression that it is one of the organisms which indicates extreme pollution. There are other organisms which are far more important. In the heavily polluted sections of the Mississippi River *Chironomus plumosus* is not found in abundance.

Dr. Johnson: The point that Mr. Olson raises is in line with my findings. At the entrance of the river into the lake there was a high count of sludge worms, and throughout the rest of the lake there were relatively few and a high chironomid count, which would indicate that the situation throughout the lake as a whole was better than at the entrance of the river into the lake.

Mr. Langlois: Has Dr. Johnson considered the possibility of producing these midge larvæ quantitatively so that they might be used as a natural diet for hatchery fish.

Dr. Johnson: The easiest way to get chironomid larvæ is to take them out of Lake Pepin. I do not know whether it would be practicable to raise them in confinement. It is hardly likely, however, that with even the greatest care you would get a much higher concentration of larvæ than occurs naturally.

Mr. Olson: Dr Purdy, of the United States Public Health Service, informed me that he understood that chironomid larvæ could be grown by the addition of a small amount of milk to the test pond. Of course the addition of milk has to be regulated carefully.

Dr. H. S. Davis (Washington, D. C.): I understand that Dr. Needham of Cornell, who has been doing some work along that line, has not been successful so far in raising them on a large scale. I think there is no question that the chironomids form a most important item in the food of our fishes. Some preliminary observations indicate that chironomid larvæ form almost the sole food of brook trout in certain Vermont streams during the winter and also, of course, a very important part of their food later in the season. I have seen a wild brook trout six inches long feeding on chironomid larvæ. He would dive down to the bottom, pick up a mouthful of sand, work it over his mouth, spit it out, dive down and take up another. He continued for half an hour while I was watching, and was still going strong when I left. In our raceways and ponds, crowded as they are, trout five or six inches long feed to a very considerable extent on chironomid larvæ, in addition to artificial food. I was also interested to learn that Miss Ward has found chironomid larvæ to be an important item in the food of young bass and fingerlings. We cannot overestimate the importance of chironomid larvæ in our fish cultural operations.

THE USE OF SUBSTITUTES FOR FRESH MEAT IN THE DIET OF TROUT

By H. S. Davis and R. F. Lord

U. S. Bureau of Fisheries

One of the most important items in the budget of the average trout hatchery is the amount expended for food. This food bill is at present getting its full share of attention since it is showing an annoying upward tendency from year to year. The increase, as you all know, is partially due to the advance in meat prices and, in the case of state and federal hatcheries, to the growing sentiment in favor of larger and larger fish for stocking purposes. When a hatchery could get rid of its fish as fry or small fingerlings, the price of food was of little importance, but holding and feeding the fish until they reach a length of several inches is a very different matter. Under these conditions every progressive trout culturist finds himself wrestling with the problem of keeping his food bill as low as possible without detriment to the fish.

With this purpose in view the bureau has been carrying on feeding experiments for several years at its experimental hatchery at Pittsford, Vt. In these experiments the object has been to hold the fish under conditions similar to those in the average hatchery, and to guard against possible error due to inherent characteristics of individual fish by making the feeding lots sufficiently large. In our experiments with fingerlings we have used lots containing from 1000 to 1500 fish held in standard hatchery troughs. Yearlings on experimental diets have been held in outdoor raceways in lots containing about 200 fish each.

During the past three years we have been giving special attention to the value of dried products as substitutes for fresh meats, since, for the average hatchery, the use of such products appears to offer the most practical method of reducing that constantly increasing food bill. Our experiments have shown that there are several dried products on the market which can be substituted for a considerable proportion of the fresh meat with results comparable with those obtained from fresh meat alone. In some cases the results have even been superior to those obtained from a straight diet of fresh meat. In short, as a result of our experiments we feel justified in asserting that, with the possible exception of those hatcheries situated near a local supply of very cheap meat, it is advisable in the interests of economy to feed a mixture of meat and dry products rather than a straight meat diet.

While we feel that we can unreservedly recommend the use of certain dried products to be fed in combination with fresh meats, we also wish to state just as strongly that their use must be regulated by good

hard common sense. There are a number of things to be considered in order to get the best results from the use of these dry products. In the past there has been a tendency to place too much emphasis on the nutritive elements in the food and too little on its physical consistency and palatability. Of what avail is it to feed foods high in proteins, carbohydrates, fats and other necessary constituents in their proper proportion if the fish refuse to eat them? In many instances we have found that the growth and vigor of young trout is in direct proportion to the amount of food which they consume. Very frequently when fish are not doing well on what theoretically should be a satisfactory diet, we have found that they are eating only a portion of their food. This is especially true when using a combination of meat and dry products; in many instances the fish simply pick out the meat and leave the rest. In this respect, one of the most surprising results to us is that with certain combinations the fish will eat the entire mixture, while with others, differing only in the meat constituent, they will simply pick out the meat and leave the rest uneaten. Consequently, in making up food combinaions every effort should be made to produce a mixture which will be readily eaten by the fish with as little waste as possible.

Small trout, of course, show a much greater tendency to select only certain constituents of the food than do the larger fish, and for this reason it seems inadvisable to attempt the use of dry products until the fish have reached a length of about two inches. Although in some instances we have obtained good results with smaller fish, it is probable that in ordinary hatchery practice it will be better to wait until the fish are large enough to eat quite coarse pieces of the mixture, which then need not be broken up into finely separated particles of the meat and dried meals.

Even with two and three inch fingerlings, the dried products which can be fed successfully are very few. First among these is clam meal, which is manufactured from the co-called "clam heads." We have now fed this meal three seasons in succession and it has consistently given us the best results of any dry product we have tried. In fact, fingerlings kept on a ration of beef liver and clam meal are showing a better growth and lower mortality than those on the beef-liver-beef-heart mixture, which all our experiments have shown to give the best results of any straight meat diet. Dried buttermilk is a close second to clam meal and has the decided advantage of being obtainable in quantity, while the supply of clam meal is very limited. Dry skim milk has also given good results with small fingerlings, but we believe the buttermilk to be superior to skim milk as a fish food. For one thing, it can be fed with less waste than the skim milk which is quickly soluble in water. These three are the only dry products which we can recommend at present for use in the diet of young fingerlings, although it is probable

that desiccated salmon eggs, used with success at the Bozeman station, will also prove to be a desirable food for fish of this age.

After the fingerlings have reached a length of four to five inches, a considerably wider range of dry foods is available. These include vacuum-dried fish meals and shrimp meals. Although these products do not produce so rapid a growth as clam meal and the dried milks, they are considerably cheaper than the latter, and can, of course, be procured in any quantity.

While trout can undoubtedly utilize cereals to some extent when properly cooked, we are not yet convinced that they form a desirable addition to their menu. We believe that at present prices, fish and shrimp meals are more economical than cereals, since in our experiments they have always given results superior to those obtained with the latter. Large fingerlings and yearlings may make a quite satisfactory growth on a ration of fresh meats and cereals, but it is doubtful if the fish are as hardy and vigorous as those reared on a non-cereal diet.

The methods employed at various hatcheries in feeding dried products differ quite widely. In a few instances the dried products are fed straight, the fish being given in addition an occasional meal of fresh meat. More often the meals are first mixed with more or less fresh meat and we believe that, in general, this method is greatly to be preferred. In many of our experimental rations, however, the dry meal used was first moistened with hot water until it formed a thick mush before incorporating it with the ground meat, but it will probably be preferable in ordinary hatchery practice to add the dry meals directly to the ground meat without any preliminary moistening. This latter method makes a somewhat more concentrated food and, too, the dry products can absorb the meat juices more completely. If the mixture is allowed to stand for a short time before being fed, the dry particles will have become sufficiently softened so that the fish will take them readily.

As high as 25% of the clam meal or dried buttermilk will give good results with small fingerlings, but it is probable that a larger percentage of the dried product would result in a considerable amount being wasted. With large fingerlings and yearlings, however, a much larger percentage of the meals can be used to advantage.

And now a word as to the meat element of the rations. In our experiments we have found that young fingerlings receiving beef liver as the meat constituent have done much better than those where other meats were used, and we still believe that despite its higher price beef liver will in the end prove a more economical food for these young fish. In the case of the larger fish a much greater variety of fresh meats are available. Pig liver can be used successfully and at present prices we believe it to be preferable to sheep plucks, which at many hatcheries

form the principal food of the older fish. The sticky consistency of the ground pig liver makes it an ideal binding medium for the dry products, but this is probably not the whole explanation, since in our yearling experiments sheep plucks have yielded the poorest results of any straight meat diet we have tried.

In this paper we have attempted to state as briefly as possible some of the more important conclusions which we have reached as a result of our feeding experiments. No doubt we shall find that some of these conclusions will require more or less extensive modifications in the future, but it is safe to say that as a trout food, the use of dry products of animal origin is no longer on an experimental basis. We can just as confidently assert, however, that these dry products can be fed successfully only in combination with fresh meat and any attempt to rear trout for any great length of time on dry products alone is doomed to certain and inevitable failure.

XVII.—Discussion

Mr. E. L. LeCompte (Maryland): Is the dried buttermilk to which you referred put up in powdered form?

Dr. Davis: Yes, the common form is granulated.

Mr. LeCompte: Does the buttermilk which the creameries put up in tub form work as well as powdered or dried buttermilk?

Dr. Davis: It is slightly cheaper but it is uneconomical to use as compared with the dried product, for the reason that it is impossible to feed it without considerable loss.

Mr. LeCompte: We are using tub buttermilk at the State game farm for bobwhite quail and wild turkeys, and we find that it works much better than the powdered form.

Dr. Davis: We have always found that there is a considerable waste in consolidated buttermilk. As a matter of fact we have one lot of fish now on a ration of forty per cent liver and sixty per cent of consolidated buttermilk, and there is so much waste in buttermilk and the appetite of the fish is so stimulated that they are actually getting more liver than if they were being fed on a straight liver diet. The dried buttermilk is simply moistened and mixed with the ground meat. Dried buttermilk unlike dried skim milk is not soluble in water.

Mr. H. L. Canfield (Minnesota): Would sour milk give the same results as buttermilk?

Dr. Davis: We have not tried it, but I see no reason why it should not. Of course many hatcheries have been feeding sour curdled milk for many years. My great objection to that practice is the loss involved. Of course if you could get cheap sour milk the waste would not matter.

Mr. Canfield: Your point with regard to the necessity of mixing these foods with a meat diet is well illustrated by the experience of a commercial dealer near Lacrosse. He fed adult fish almost exclusively on cottage cheese, and last fall he had considerable loss because continuing too long on a one-sided diet he had produced a deficiency disease. When he commenced feeding a fifty-fifty diet, the disease disappeared in a few weeks.

Mr. Eben W. Cobb (Connecticut): Would Dr. Davis state how much of the shrimp meal he would recommend using, and what particular virtue it possesses?

Dr. Davis: The term "shrimp meal" is commonly used for any form of dried shrimp refuse from the shrimp canneries. The coarser form is known as shrimp bran, but the finer grade is called shrimp meal, which we use for the small fish. For fish to five or six inches in length the bran is better than the finer meal. Shrimp meal has a high chitin content which is indigestible, and for that reason possibly it does not give results comparable to those obtained with the dried buttermilk or clam meal. On the other hand, it is much cheaper; you can buy it for two or three cents a pound. The price of clam meal is ridiculously low at the present time, but the supply is scarce. Dried buttermilk ordinarily costs about eight or nine cents a pound. For the larger fish I think the shrimp bran or shrimp meal is a desirable addition to the trout ration.

Dr. J. Metzelaar (Michigan): In those states where trouble is experienced with goitre would Dr. Davis recommend, in addition to the regular meat diet, iodine-containing drugs, or would he advise the feeding of elements in the diet of marine origin that are high in iodine content?

Dr. Davis: I consider that shrimp bran is an ideal food from that standpoint, since it is relatively high in iodine. I would prefer it to drugs. As a matter of fact I do not know that any of the Bureau's hatcheries are having any trouble with goitre at the present time. I believe any of the dried foods of marine origin such as clam meal would fulfil the same purpose.

Mr. J. A. Rodd (Canada): Has Dr. Davis anything to say with regard to the value of the carcasses of Pacific salmon after they have spawned?

Dr. Davis: No, we have not tried that food.

President Culler: In Utah suckers and other undesirable fishes are canned for use as trout food.

Mr. Farley (California): In Oregon they freeze smelt and the carcasses of spawned salmon, hold them in cold storage and later after grinding use them successfully for feeding salmon. I would like to ask concerning the proportions of the shrimp meal that Dr. Davis is feeding to the larger sized trout.

Dr. Davis: The experiments which we are carrying out with various proportions of these feeds have not yet been completed. From our previous experience I should say you can undoubtedly use at least fifty per cent of shrimp bran.

Mr. LeCompte: At what age do you start feeding shrimp and clam meal?

DR. DAVIS: We started some of our feeding experiments on trout which had been feeding only about two or three weeks, but in ordinary hatchery practice I doubt whether it is advisable to start on any dried products until the trout reach a length of two inches. With the shrimp bran I would wait until they are three or four inches long.

MR. D. H. MADSEN (Utah): We began to use canned carp and suckers for fish food about three years ago in Utah. Last year we fed nearly 100 tons. Carp are preferable to suckers for this purpose because they do not contain much oil. It is the most satisfactory food we have ever found, from the very early stages throughout the entire time the fish are held in the hatcheries. The fish are healthier and the growth is better.

DR. DAVIS: For the last two years our standard feed at the Pittsford station for trout one year old and over has been a mixture which contains only fifty per cent of fresh meat and fifty per cent of dried shrimp bran and clam meal. I do not believe there is a finer lot of fish anywhere than at our Pittsford hatchery.

MR. F. W. WESTERMAN (Michigan): I would ask Dr. Davis the proper age at which young trout should be transferred from beef liver to some other type of food. Since we use sheep liver almost exclusively in Michigan, I note with considerable interest the statement of Dr. Davis that he has found beef liver, even at present prices, to be preferable to any othr food.

DR. DAVIS: The choice of liver depends on the species of trout. In the case of sheep liver, for instance, we have found it gives much better results with rainbow than it does with brook trout. In the case of brook trout I do not believe I would recommend changing from the beef liver to some other meat diet until the fish reach a length of four or five inches. For brook trout we prefer pork to sheep liver. If you are going to change from beef liver, I suggest, on the basis of our own work, changing to pork rather than sheep liver, when the trout are about three to three and a half inches long. On the other hand I do not think that there is any question that they will show better growth if they continue on beef liver for a somewhat longer time. After they reach four or five inches they will give a splendid growth if pig liver is used as a basis of the meat constituent.

MR. WESTERMAN: After our brook trout have reached a size of one and a half inches the majority are transferred to rearing stations, in which they may get more or less natural food. We feel that our fish are showing excellent results on the sheep liver diet. Our brook trout have a tendency to develop goitre, since Michigan water is notoriously deficient in iodine.

PRESIDENT CULLER: A point that has not as yet been mentioned is the percentage of losses with the different foods. Even if a food with a low death rate cost a little more, it would be economy to use that food instead of one which gave a higher rate. Perhaps Dr. Davis could give us the relative mortality with the several foods.

DR. DAVIS: In our experimental work, although we developed some unsatisfactory diets and marked differences in growth, we have not found a great deal of difference in the losses. The absence of any considerable variation in the losses is due largely to the fact that we were not using the more undesirable diets.

MR. CRARY (Wisconsin): I have a letter from Dr. Embody which gives a formula for feeding which may be of interest:

> "In regard to larger fingerlings above two and one-half inches, the greater part of their food should be fresh meat, but we find it advantageous to gradually begin the introduction of fish meal or meat meal. At first we mix a very little with the melts but when the fish average above three inches the fresh meats are fed alone in alternation with the following mixture:

Finely ground wheat or barley feed	20 parts
Finely ground fish meal	35 "
Finely ground animal meal	30 "
Skim milk powder	15 "
	100

We have used shrimp bran and find it advantageous. but perhaps the fish meal is a good substitute.

DR. DAVIS: Yes, the fish meal takes the place of the shrimp meal.

MR. CRARY: Is there any difference between the shrimp bran and the fish meal?

DR. DAVIS: No. we have obtained comparable results from the two. The shrimp bran is a little cheaper than the fish meal.

MR. J. A. RODD (Canada): What ration or combination would Dr. Davis recommend for improving the quality and quantity of egg production in brood stock?

DR. DAVIS: I have no information on this subject. We are planning next year to start some experiments on this problem.

DR. EMMELINE MOORE (New York): Is it generally known that the buttermilk powder is available? I notice that in Dr. Embody's formula he mentions dried milk, and apparently that is less efficacious than dried buttermilk. Is the dried buttermilk on the market as a regular product?

DR. DAVIS: Yes, the dried buttermilk we are getting comes from the Collis Products Company of Clinton, Iowa, but other firms manufacture it.

DR. EMMELINE MOORE: Is dried buttermilk bound together by anything which makes it insoluble in the water so that the fish get the whole substance?

DR. DAVIS: They get the whole food. The process of manufacture is more or less secret. In Vermont it is dried in a vacuum and then ground very fine. The Collis product is in two forms, coarse and fine, but even the fine is a little too coarse for small fingerlings, and it is necessary to grind it.

Mrs. P. K. Nurnberger (Minnesota): There are about eight dried buttermilk creameries in Minnesota. The buttermilk is held at a high temperature. It comes over a drum in a sheet, then it is chopped up and shipped out in sacks.

Mr. Crary: Is buttermilk the same as the milk powder?

Dr. Davis: No, it is different from the milk powder and possesses a great advantage over milk powder as a trout food in that it is not soluble in water. Milk powder is water soluble and for that reason is difficult to feed without considerable waste. Dried buttermilk in itself is no better food than the milk powder.

Mr. Dell Brown (Arkansas): Have you ever tried feeding gar meat to trout?

Dr. Davis: No. As a matter of fact the few experiments we have made with fresh ground fish have not been as successful as those with other foods.

Mr. Dell Brown: You do not think the gar meat would be as good a food as carp or suckers?

Dr. Davis: I am a little afraid of gar meat, because the eggs contain a toxic product, and I am not sure that the flesh might not also be injurious.

Mr. Dell Brown: The flesh would be more oily, would it not?

Dr. Davis: I should think the difficulty and labor of preparing it would make it an expensive food, even if you got the fish for nothing.

Mr. Dell Brown: We could well afford to expend the labor to get rid of the gar.

Dr. Davis: It would help exterminate the gar.

Mr. Crary: I understand that Dr. Embody is quite an authority on these subjects, and if you will bear with me I will just read a further extract from his letter:

"Although we are not sure of the way in which trout are benefited by curd, it is believed that it not only supplies calcium in which the meats are deficient but also acts as a corrective for certain intestinal troubles. The calcium could just as well be supplied by skim milk powder, but the other benefit is believed to be derived from certain bacteria occurring in the curd, and which are absent, in the active condition at least, in the dried milk."

I wonder if there would be a loss of calcium in the dried buttermilk.

Dr. Davis: No, I do not think there would be any loss. Of course the bacteria would be killed in the process of manufacture.

A RIVAL TO LIVER

W. T. Thompson

U. S. Fisheries Station, Bozeman, Montana

I have come here to present to you an exhibit of trout fed on prepared, dried feed under distinctly unfavorable conditions, hoping that this exhibit will be more eloquent than any speech of mine could be.

Montana, as you all know, is a State of high latitude and high altitude accompanied by low temperatures both as to water and air, and a short growing season. I will ask, therefore, that you do not judge my exhibits by the results you are able to attain under more favored conditions, and with longer growing seasons.

Liver has always been the favored food with the trout culturist. Confronted with the ever increasing cost of liver we looked about for promising substitutes.

The great streams of the Pacific-Northwest and of Alaska had long teemed with a seemingly inexhaustible abundance and wealth of splendid salmon. This former abundance has been lessened by prodigal harvesting and by the exploitation of the canneries, which has resulted in the destruction of untold tons of potential salmon in the form of the imperfectly developed and unfertilized eggs.

Several years ago, some students of the School of Fisheries of the University of Washington, conceived the idea of converting the eggs, by process of dehydration, into a food for the Salmonidae, of which I shall tell you more later.

We have another potential trout food in the thousands of wild horses which roam the ranges of the Northwest and portions of the Southwest, feeding on the grass which might more profitably be consumed by wild game or the tame flocks and herds. There are dozens of establishments in the west and even in the Mississippi Valley for slaughtering horses and canning them for European consumption, as well as manufacturing poultry and fox foods.

Bozeman Station was one of the early experimenters with fresh horse flesh and livers for trout food, the former appeared to proffer no special advantages but the latter was found even better than beef liver, having a texture and firmness more like beef hearts without the excessive loss in preparation of beef hearts or the milkiness of beef liver when fed. It likewise goes farther than beef liver when fed fresh.

Last fall and winter we collaborated, to a slight extent, with one of the Southwestern horse killing establishments in their efforts to produce a dry, prepared trout food. We likewise heard most encouraging reports of results from experiments on the Pacific Coast with the

dehydrated salmon eggs—these were the basis of our feeding experiment of the season now drawing to a close.

The Arizona Reduction Works, Inc., of Phoenix, Arizona, contributed four samples and the Neptune Fish Products Co., of Seattle, contributed one. The fish used for our experiment were hatched from brook trout eggs voluntarily contributed by the Southside Sportsmen's Club, of Oakdale, Long Island. These were late taken eggs, hatched January 21st and commenced feeding February 15th.

The experimental foods were not all on hand on this date, so we commenced feeding fresh beef hearts, livers and horse livers, adding the prepared foods to the menu as fast as they were received. The experiment was actually commenced March 1st when the five experimental troughs were fed strictly and solely on the prepared foods with the sixth or control lot fed on the usual Hatchery ration of fresh horse liver with some admixture of beef hearts and beef liver—all too frequently supplemented by hog liver.

We originally intended to conduct the experiments on a strictly scientific basis, but—our foreman was sent to Glacier Park where he made some most interesting discoveries as to the spawning period of the Black Spotted Trout, definitely determining that in one lake, at least, these fish spawn in mid winter under five to twelve inches of ice and with a water temperature of 35 degrees on the spawning grounds.

Our fish culturist, Wallace R. Newcomb, who had commenced the experiment, was called to the salmon work in Alaska, leaving us with but two apprentices to carry on the general work of the Station. It became necessary, therefore, to drop the scientific aspects of the experiment and continue it merely as a practical feeding demonstration, conducted by apprentices and during much of which experimental period, the superintendent was necessarily absent. The success of this work speaks most highly for the zeal of apprentices, Leonard Hunt, and LeRoy Harris.

All of these foods were taken readily and freely by the trout when first offered.

I have heard that a sole diet of sugar, while fattening, is not life-sustaining. We soon found a somewhat similar condition facing us with three of our horse foods—nevertheless, we continued to feed the food for some time to determine definitely whether the mounting death rate was merely temporary, or was a permanent result of the continuous sole feeding of the test rations. When this was definitely determined, we set about to check up and determine whether these foods proved unsatisfactory as a sole ration, might not be valuable as a substitute or supplementary food, say, on a 50-50 basis, combined with the two remaining more satisfactory foods and with the standard ration of beef liver.

We were feeding the trout four times per day, so we continued with two feeds of the test food, fed alternately with two feeds of salmon eggs, liver meal, and fresh liver. All lots quickly responded to these varied changes in diet and the death rate practically ceased. Our theory as to supplementary food values being definitely proved, we eliminated these troughs, owing to congestion and lack of time. We were, however, on the trail of a food which could be used solely as a rival to liver; so we continued work with the salmon eggs and liver meal, with a control lot fed on fresh liver and hearts, notwithstanding that we were freely and frequently told that no dry food would stand this test and that an occasional feed of fresh liver was necessary—the more frequent, the better.

After three or four months, the trout fed on the salmon eggs began to crack, though not badly, so this food was eliminated. We continued our test with the liver meal, and we are still feeding this liver meal solely and successfully. The test will continue at least until these living fish can be shown our Mr. Leach, of Washington, and Mr. Culler, of LaCrosse, after the close of this meeting.

For those of you who cannot visit Montana with us, I have prepared some specimens. These trout have been held in troughs continuously with a water temperature ranging from 44 to 46 degrees and given merely ordinary hatchery attention. We have larger fish in our ponds. As you can see this food is fine and powdery. In ordinary practice I would not recommend its use for trout much above the fingerling No. 2 stage on that account, nor would I recommend it very warmly for use in ponds, although the specimens shown you range from four to four and a half inches in length and are built in proportion. For these largest fingerlings to make a living on this powdered food is much the same as though you gentlemen tried to eat soup with an after dinner coffee spoon. You would tire before you were filled.

Very greatly to our surprise, we found that the trout fed solely on liver meal grew a little more rapidly up to the two and a half to three inch fingerling stages than those fed on fresh liver. They appeared slightly more active, and were certainly darker and more virile in appearance. We tested these latter features frequently using our visitors for that purpose, both fish culturists and others, and never once did the test fail.

Up to three inches, the test was favorable to the liver meal, but as the control lot of trout grew, we increased the coarseness of liver and heart food which we could not do with the meal, so the former gradually overtook and have now slightly, but only slightly, outgrown their liver-meal-fed brothers. Permit me to give you some figures which will illustrate the points I have endeavored to stress:

NUMBER OF FISH TO THE OUNCE

	March 1st	April 1st	May 1st	August 29th
Salmon Eggs	160	45	24	
Beef Liver and Heart	160	43	26	4.29
Horse Liver Meal	160	40	21	4.75
50-50 Fresh Liver and Liver Meal				4.33

Neither the liver meal nor the salmon eggs tend to make the water milky, nor do they foul the trough to the same extent as does liver. Uneaten salmon eggs and fresh liver fungus while the liver meal is almost immune. Again, neither of these dry foods require preparation —hence there is no shrinkage;—no expensive refrigeration is required and the foods can be kept indefinitely;—hence they are available at all times. They should, therefore, be of exceptional value in the more isolated sections where hatcheries and rearing troughs and ponds are maintained.

Our experiments demonstrate that one pound of this dry food, either salmon eggs or liver meal, is equivalent to two to three pounds of fresh liver.

I'll leave it to you from the exhibits I have presented and the statements I have made whether liver has a rival.

XVIII.—Discussion

DR. H. S. DAVIS (Washington, D. C.): I was at Bozeman early in June and I can certainly corroborate all that Mr. Thompson says about the appearance of these fish reared on the dry foods. They were as vigorous and healthy a lot of trout as I have ever seen. But I am still not entirely convinced that you can keep trout indefinitely on dry foods; in fact I am positive that it cannot be done under ordinary hatchery conditions. Our attempts to keep trout on dry foods indicate that they simply will not eat it half the time. Of course we have not tried this particular liver meal, but we have tried various combinations of dried foods, served in appetizing fashion, with no effect. The fish simply refused to take them in any quantity, and half the time would begin to die rapidly. On the other hand, if you give them fresh meat occasionally, it makes all the difference in the world. Unquestionably the results that Mr. Thompson has been getting there are of a great deal of interest, because that is by far the longest time I have ever known trout to have been kept on purely dry food. Even if we find under other conditions that we cannot keep them indefinitely on dry food, it certainly looks as if this liver meal and dehydrated salmon eggs would make an ideal food in combination with small quantities of fresh meat.

MR. H. L. CANFIELD (Minnesota): May I ask whether the samples Mr. Thompson has shown us are average size or selected specimens?

Mr. W. T. Thompson: I have given you the average weight in my paper. These specimens are slightly above the average. They show no evidence of starvation.

President Culler: Mr. Thompson has every reason to be proud of his output this year; he has had a wonderfully fine lot of fish.

Mr. J. F. Comee (Illinois): Have there been any experiments in the way of mixing the powdered liver with mush food or middlings as is done with the raw liver for the larger fish?

Mr. W. T. Thompson: I have never found any result from the use of mush food except to foul the ponds, although some have had considerable success in feeding various products of wheat, oats and beans.

Mr. Canfield: I was just wondering whether Mr. Thompson could furnish the names and addresses of the dealers in dried liver, and the approximate price of the product; also the quantities in which it can be obtained.

Mr. W. T. Thompson: The dehydrated salmon eggs are put up by the Capital Fish Foods Company, Incorporated, 404 White Building, Seattle, at a price of ten cents at Seattle. The Purity Brand liver meal is put out by the Arizona Reduction Works, Incorporated, of Phoenix, Arizona, at twenty cents a pound. The Miles City Horse Company, Illinois, expected to furnish samples for experimental work at a price not to exceed $10. The Swift Company, if they succeed in making their production, will not exceed this price.

Mr. Canfield: You consider that a pound of this prepared food would go further than a pound of liver?

Mr. W. T. Thompson: A pound of the prepared food will probably go three times as far as liver as it is purchased.

Mr. Canfield: Is the entire liver used in the preparation of the dried product or are the parts removed as when used in the raw form?

Mr. W. T. Thompson: I do not know.

Mr. Crary (Wisconsin): Would you recommend feeding trout from the commencement of the feeding stage of fry?

Mr. W. T. Thompson: We found that it was not necessary to accustom the fry to these dry foods since they took it readily from the first. In fact, we find it particularly valuable on account of its being all ready prepared. In order to prepare fresh liver or hearts for young fry it is necessary to grind and regrind it numerous times in order to get it fine enough. We have not experimented with this food long enough to determine whether it is advisable to feed it solely from the beginning. We have met with success in many small lots by feeding it from the beginning; but in general we have given the small trout both feeds, because we did not feel that we could risk the loss of several millions of young fry by the exclusive use of this food while it was still in the experimental stage.

Mr. Crary: Does it float, or sink to the bottom?

Mr. W. T. Thompson: That is one very desirable feature of it, except for a few heavier particles it rests on the top of the water, and it is interesting to watch the fish jump at it.

PLANT AND ANIMAL ASSOCIATIONS IN A LAKE

PATIENCE KIDD NURNBERGER

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The association of plants and animals in a lake exists in a definite and necessary chain of relationships. It is well known that in the food chain of fishes the larger fishes eat smaller fishes; the smallest fishes eat crustacea, adult insects and their larvae; the larvae feed upon algae which is the microscopic plant life present in the water. Therefore the natural association of plant life, algae in particular, with animal life must be known if a sufficient food supply is to be maintained for our game fishes. The following information was obtained from a study and investigation of Big Sandy Lake in Aitken County, Minnesota, a lake well known for wall-eyed and northern pike.

The various associations in a lake can be classified into three groups: the blanket algae, the plankton and the higher plants. The blanket algae association consists of filamentous forms either floating in masses or attached to twigs, gravel or rocks. The plankton association includes all free floating forms of animal and plant life found in the lake. The growths of higher plants consist of the various attached aquatic plants and the associated animal life.

In the floating masses of filamentous algae, several genera dominate the group. The most common genera in this lake are Spirogyra, Mougeotia, Oedogonium and Zygnema. The animal population consists of Dipterous larvae, pupae and adults; nymphs of Ephermida; and the adults of Hemiptera and Coleoptera. Among the crustaceans, Gammarus and Hyalella are found in large numbers, also Cladocerans and Copepods with their nauplii. Snail shells are found entangled in the filaments of the plant life. Among the masses of attached algae, there are found various types of associating algae depending upon the attachment to twigs or rocks and upon the amount of wave action. The varius genera, Spirogyra, Oedogonium, Stigeoclonium and species of Cladophora are dominant forms in the various types of attached algal masses. Larvae of Diptera and Coleoptera and the pupae of Diptera with Cladocerans and Malacostracans are found in the group of attached algae which are growing upon stones and rocks. The following list enumerates all forms found in the blanket algal association.

Plants	*Animals*
Myxophyceae. Blue-green algae.	
Microcystis flos-aquae (Wittrock) Kirchner	Protozoa
Coelosphaerium Nagelianum Unger	Difflugia
Aphanothece repens A. Brown	Rotatoria

Anabaena flos-aquae (Lyngbye) de Brebisson
Anabaena Lemmermanni P. Richter
Anabaena planctonica Brunthaler
Anabaena spiroides var crassa Lemmerman
Cylindrospermum minutissimum Collins
Cylindrospermum stagnale Bornet & Flah.
Aphanizomonon flos-aquae (L.) Ralfs.
Phormidium autumnale (Agardh.) Gomont.
Phormidium uncinatum (Agardh.) Gomont.
Phormidium retzii (Agardh.) Gomont.
Tolypothrix distorta (Hofman-Bang) Kutzing.
Gleotrichia echinulata (J. E. Smith) P. Richter

Bacillariaceae. Diatoms
Navicula viridis Kg.
Cymbella tumida Brebisson
Gomphonema geminata Lyngbye
Synedra biceps (Kutz.) A. S.
Fragilaria crotonensis Kitton
Tabellaria fenestrata Kg.
Stephanodiscus astraea (Ehr.) Grun.
Melosira granulata Agardh.

Chlorophyceae. Green algae
Cladophora crispata (Roth) Kutzing ampl. Brand
Cladophora glomerata (L.) Kutzing ampl. Brand
Cladophora fracta Kutzing
Pandorina morum Bory.
Volvox sp.
Pediastrum Boryanum (Turpin) Menegh.
Scenedesmus quadricauda (Turpin) Breb.
Closterium sp.
Cosmarium sp.
Cosmarium Wittrockii Lund.
Desmidium Swartzii Ag.
Zygnema cruciatum (Vauch.) Kutzing
Spirogyra crassa Kutzing.
Spirogyra longata (Vauch.) Kutzing.
Spirogyra varians (Hass.) Kutzing.
Spirogyra sp.
Mougeotia genuflexa (Dillw.) Agardh.
Stigeoclonium nanum (Dillw.) Kutzing.
Cylindrocapsa sp.
Oedogonium Richterianum Lemmerman.
Oedogonium sp.
Bulbochaete intermedia de Bary
Bulbochaete insignis Pringsheim

Anuraea
Oligochaete
Stylaria
Hirudinea
Placobdella
Cladocera
Simocephalus
Daphnia
Bosmina
Copepoda
nauplius
Ostracoda
Malacostraca
Hyalella
Gammarus
Insecta
Hemiptera
Copeoptera
Diptera
Insect larvae
Ephermida
Coleoptera
Trichoptera
Diptera
Insect pupae
Diptera
Bryozoa
Mollusca
Amnicola
Limnea
Neoplanorbis
Planorbis

The plankton life of a lake is dominated at various times by either blue-green algae or diatoms. When the blue-green algae are dominant, the condition which is known as "water bloom" is present. Among the colonies and filaments are found Cladocerans, Copepods, Rotatoria and Protozoans. These microscopic animals are continually feeding upon the plant life surrounding them. For example, the protozoan, Vorticella, attaches itself to a filament of Anabaena and absorbs the

protoplasts of the algae. The following list includes all the life found in the plankton:

Plants

Myxophyceae. Blue-green algae.
- Microcystis flos-aquae (Wittrock) Kirchner
- Microcystis pulvurea (Wood) Migula
- Coleosphaerium Nagelianum Unger
- Anabaena augustumalis var. marchica Lemmerman
- Anabaena contorta Bachman
- Anabaena flos-aquae (Lyngbye) de Brebisson
- Anabaena flos-aquae var Trealeasii Bornet & Flahalt
- Anabaena Lemmermanni P. Richter
- Anabaena planctonica Brunthaler
- Anabaena spiroides var crassa Lemmerman
- Aphanizomonon flos-aquae (L.) Ralfs.
- Oscillatoria geminata Meneghini
- Gleotrichia echinulata (J. E. Smith) P. Richter

Peridiniaceae—Flagellates
- Ceratium sp.

Bacillariaceae. Diatoms
- Diatoma vulgare Bory.
- Synedra biceps (Kutz.) A. S.
- Asterionella gracillima (Hantz.) Heib.
- Fragilaria crotonensis Kitton
- Tabellaria fenestrata
- Stephanodiscus astraea (Ehr.) Grun.
- Melosira granulata Agardh.

Chlorophyceae. Green algae.
- Pandorina morum Bory.
- Volvox sp.
- Pediastrum Boryanum (Turpin) Menegh.
- Closterium sp.
- Zygnema cruciatum (Vauch.) Agardh.
- Bulbochaete intermedia de Bary.

Animals

Protozoa
Vorticella
Rotatoria
Anuraea
Cladocera
Bosmina
Ceriodaphnia
Chydorus
Daphnia
Ophryoxus
Copepoda
nauplius
Canthocampus
Cyclops
Diaptomus
Ergasilus
Ostracoda
Insecta
Gyrinidae
Insect larvae
Chironomus

The higher plants are found along the muddy shores and in shallow parts of the lake. The dissected leaves offer a large space for cases of insects and shelter of other animals. A list of the plants found in the lake follows:

Potamogeton interior Rydberg
Potamogeton praelongus Wulf.
Potamogeton pectinatus L.
Potamogeton heterophyllus Schreb.
Potamogeton pusillus L.
Potamogeton zosterifolius Schumacher
Potamogeton Richardsonii (Benn.) Rydberg
Scirpus validus Vahl.
Scirpus atrocinctus Fernald.
Sagittaria cuneata Sheldon
Spartina Michauxiana Hitchc.
Sparganium eurycarpum Engelm.

Zizania aquatica L.
Acorus Calamus L.
Calamagrostis canadensis (Michx.) Beauv.
Calamagrostis Lanksdorfii (Link.) Trin.
Nymphaea advena Ait.
Utricularia vulgaris L. var. americana Gray.
Alisma plantago-aquatica L.
Najas flexilis (Willd.) Rostk. & Schmidt.
Polygonum Muhlenbergii (Meisn.) Wats.
Myriophyllum sp.
Boltonia asteroides (L.) L'Her.
Sium Cicutaefolium Schrank
Solidago graminifolia (L.) Salisb.
Stachys ambigua (Gray) Britton
Potentilla monspeliensis L.
Lemna trisulca L.
Lemna minor L.
Riccia fluitans
Elodea sp.
Nitella sp.

Thus in all conditions of nature, there is present a natural balance between groups of plants and animals. In the filamentous algal masses, the plankton and the vegetation, there exists specific relationships between the plants and animals, for the photosynthetic plant life presents a home and food for the animals.

XX.—Discussion

MR. A. F. BYERS (Montreal): During what months was this study conducted?

MRS. NURNBERGER: I have spent every summer at Sandy Lake since 1925, usually from the first of June until the first of October.

MR. J. N. LOWE (Michigan): How old were the fish?

MRS. NURNBERGER: All the fishes I have studied up to the present time have been under seven inches.

MR. THADDEUS SURBER: Mrs. Nurnberger has been carrying on certain investigations for our department with particular reference to the smaller fishes in order to determine their natural food. Necessarily the fish have been mostly immature fish. The results indicate that many fish which previously have been considered carnivorous feed largely on algae. We anticipate that this study will lay the foundation for the development of natural food in lakes and streams that are becoming depleted.

"PLANT MATERIAL AND DEBRIS": THE ALGAL FOOD OF FISHES

Josephine E. Tilden

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It is the custom of those who write concerning the food of fishes, to confine themselves solely to a discussion of animal food. If they mention algae at all, it is only by way of listing them under some such general heading as "Vegetation", "Vegetable plankton", or "Plant material and debris."

As a matter of fact, the algae play a very important role, direct or indirect, in the diet of all fishes, both marine and freshwater. The subject is a highly complicated and diversified one. It embraces the contemplation of food chains; the consideration of ancient methods of fish culture; the evaluation of the significance of algae in determining conditions in fish ponds; and a study of pollution of water, its causes and effects.

The Ultimate Source of Food of Marine Fishes

In the ocean the fringe of attached algae clothing the rocks and reefs along the shores furnishes a perennial supply of food for marine animals. Hordes of invertebrates pass through all the stages of their existence in the meshes formed by the interlacing branches of this miniature submarine forest. Millions of schools of brightly colored reef fishes may be seen hovering over these seaweeds, darting swiftly from one plant to another, nipping off a branch here, a succulent fruit there, their activity not, however, due to the necessity of having to catch their prey, but to the fact that they themselves form the prey of innumerable enemies. In spite of their agility they do not always elude capture, for they furnish sustenance to larger fishes, which come in from deep water to feed upon them.

Although not generally recognized, it is the algae of the ocean, consisting of both attached seaweeds and plankton forms, that constitute the basal link in the food chain of all of our important food fishes. When these in turn are consumed by man, he forms the terminal link in the chain.

That animals can not make food is a matter of common, but generally neglected, knowledge. Plants are the only organisms able to perform that function. Marine algae, then, must manufacture all of the food consumed by marine animals.

When one stops to consider the countless numbers of creatures—ranging from microscopic organisms to huge monsters—which swim in the sea; when one contemplates the sum total of energy expended by

these animals and the amount of food required to supply this energy, it seems incredible that all of these proteins, carbohydrates, fats and vitamins had their origin in the microscopic cells of marine algae. But, this is a fact, and a fact that must be given attention.

It is time that the primary links of the food chain receive due consideration. The algae, and the animals which feed directly upon the algae, should be studied with all possible care, both as a scientific problem and as a basis for practice.

In nutritional studies attention is usually restricted to the processes by means of which the animal organism takes its food, digests it, and makes use of it for growth, movement and repair. Should not such studies be extended to include a physiological examination of the food consumed, that is, the plant organism?

But, physiology must wait upon morphology and taxonomy, for after all, no satisfactory progress is possible until one can be sure of the species of the animal which devours and of the plant which is devoured.

Writers have generally assumed that algal material found in the digestive tract of organisms has been merely taken in accidentally along with animal food. Work in the botanical laboratory has amply demonstrated the direct consumption of algal food by fishes.

It is idle to state that the small animals which live upon algae do not use selection in gathering their food. One can not affirm, indeed, that they have preferences in the way of taste, but a brief examination of their mouth parts will prove at once that these are fitted to take certain kinds of plant food and that they are physically unable to manage others.

The microscopic, unicellular algae, commonly known as "plankton", which live out their existence as floating organisms in the surface layers of the sea, are usually given the whole credit of constituting the primitive foods of fishes. I venture to predict that the larger attached algae of the continental shelf will eventually be found to be the most important contributors of food material to marine animals. The common seaweeds, covering millions of acres of submerged coast land, are engaged in manufacturing food—with energy derived from the sun—from the inorganic materials held in solution in the sea water.

Certain authorities have contended that the eelgrasses—one of the few kinds of flowering plants found growing submerged in the sea—form a source of plant food of fishes. The leafy aquatics of lakes and rivers are thought by some to be eaten by fishes. This may be true in some localities, but the writer has never seen a single shred of eelgrass leaf in the digestive tract of marine fishes, nor has she seen fragments of the tissues of higher plants in freshwater fishes. Pollen grains and fungous spores, scattered over the surfaces of lakes by the wind, are sometimes present in the food contents, but quite evidently only by

chance. Freshwater fishes often appear to be eating leafy aquatics when in reality they are taking only the slimy layer which ordinarily covers submerged stems and leaves and which is made up of living and dead diatoms, other algae, and minute animals.

In a study of the algal food of Hawaiian reef fishes some interesting facts are being discovered. Most of the species belong to the family of Butterfly-fishes, characterized by bright colors and great activity. The digestive tracts are found to be filled with algae of the kinds which grow on shore and reef.

Chaetodon Fremblii, or "Butterfly-fish", known as "Lauhau" by the Hawaiian fisherman, is between five and six inches in length and is of a bright yellow color, with narrow bands of sky-blue edged with black running longitudinally over the compressed body. An interesting thing about this fish is the conformation of the mouth parts which are nicely adapted to feeding upon algae. The snout is long, blunt and rounded, the mouth small, the jaws equal and produced. The teeth are set in brush-like bands in the jaws. According to previous reports this fish is carnivorous, but our studies have proved that it lives on a diet consisting of certain kinds of seaweed. The bits of algae found in the digestive tract range in length from 0.96 to 1.5 millimeters.

A second very common little Hawaiian reef fish, chrome yellow in color, is the "Laipala", or "Surgeon-fish", *Zebrasoma flavescens.* According to Jordan and Evermann it belongs to the family of Surgeon-fishes which comprises a group of herbivorous fishes living about coral reefs in tropical seas. Apparently it feeds entirely upon attached algae of the filamentous type. It is from three to seven inches in length and it has a pointed snout and a small mouth, with broad teeth having crenulate edges. The intestine of this fish, as might be expected from its vegetarian diet, is uncommonly long. When a sample of the stomach contents is examined under the microscope, it is seen to be made up of hundreds of small pieces of seaweed. Quite a number of different species are represented, and most of these can be identified with certainty by a trained specialist in the algae.

The most common species of Red Algae consumed by this fish is *Amansia glomerata,* which has a flat leaf-like frond made up of horizontal rows of very regular cells. Often, the bits of seaweed show the marks of the teeth of the fish. The most common Brown Alga is a species of *Ectocarpus* which usually bears numerous little cylindrical fruit bodies. From the number of fruit-bodies present in the digestive tracts, one would be led to believe that they were deliberately selected or sought by the fish. In the three specimens of this fish which were examined with particular care, the digestive tract in each case was found to be packed full of filamentous attached algae, comprising 23 species,

most of which belong to the Red Algae, distributed as follows:

Blue-green Algae	1 species.	Very common.
Red Algae	15 species.	Five very common.
Brown Algae	5 species.	Two common.
Green Algae	2 species.	Both rare.

The pieces of algae are usually of about the same length for each species of fish and frequently show tooth marks. In the case of *Zebrasoma flavescens* the bits of algae are from 2.2 to 3.4 millimeters in length.

A third reef fish which feeds upon marine algae is *Zanclus canescens,* the "Moorish Idol," the "Kihikihi" of the Hawaiian. It is a handsome little creature, brilliant yellow in color with striking black bands, and with a long curved dorsal fin. Its favorite food seems to be a filamentous blue-green alga, *Hydrocoleus cantharidosmos,* a plant often eaten by the other reef fishes as well. The alga consists of several cylindrical blue-green threads lying inside of a tubular gelatinous sheath. Isolated filaments are too small to be seen without the aid of the microscope, but since its habit is to grow in masses, it is quite visible to the naked eye.

LESSONS DRAWN FROM METHODS USED IN FISH CULTURE BY PRIMITIVE PEOPLE

The old Hawaiian fish ponds should afford interesting and important information to the fish culturists of to-day. Originally owned by members of the royal family, they were probably built several centuries ago by the labor of numbers of men working together under supervision of highly intelligent leaders. Tradition says that one pond was built by having men form a line from the mountain to the shore a mile away. They then passed lava blocks from hand to hand until the place on the shore was reached where the fish pond was being constructed. Some of these prehistoric ponds are still in use. It cost nothing to keep fish in them as seaweeds cover the rocky sides and bottom and the fish find their own food among the plants, either eating them directly or feeding upon the small animals which in turn live on the fronds.

In the Phillipine Islands great numbers of ancient fish ponds are still in excellent preservation. A number of such ponds are situated around the curve of Manila Bay. One of the most important food fishes of the tropical Pacific, and the most highly prized species of these islands, is a large fish, silvery in color, allied to the herrings. It still is reared in these ponds according to the ancient method and is sold in quantity in the market places of Manila. This is the "Milkfish," *Chanos chanos* (Forskal), known as "Bangos" in the Philippines. This species, which is without teeth, lives upon algae with, perhaps, the addition of animal forms which might be swallowed with the algae.

The fry of this fish are taken from the sea when exceedingly small and are transferred to tanks in which are growing Blue-green Algae of the species *Lyngbya aestuarii,* a filamentous form consisting of slender and delicate threads in gelatinous sheaths. This, for some time afterwards, forms the only food furnished the young fish. It is, therefore, the special "baby-food" of this important species.

After such a period of about three months, the fish are taken out and placed in a second tank in which are growing slender filamentous green algae, species of *Chaetomorpha* and *Cladophora.* These plants, resembling very much our common freshwater forms, are several times as large as the *Lyngbya* threads, and the coarser food is apparently relished by the young growing fish.

After a few months, the fish are transferred to a third series of tanks containing *Enteromorpha,* a green alga with wide flat or tubular fronds. The fish remain on this diet until ready for the market.

Now, it is not for the specialist in algae to advise the expert in fish culture, but scientific evidence should have its part in formulating suggestions for practical methods. On the basis of the foregoing evidences, concerning the algal food of fishes, might not the example of the Hawaiian and Philippine peoples—in the construction of fish ponds and feeding methods—be followed by fish culturists in the United States and Canada with a great saving of trouble and expense?

It is true that the food and game fishes of America do not live, in general, directly upon algae, but many of the smaller fishes upon which they subsist do feed upon algae. Certain filamentous "attached" algae, could be allowed or induced to grow in tanks or ponds with suitable conditions of water and temperature. Such algae are too often cleaned out of the tanks, by raking or scrubbing methods, or they are destroyed by the frequent use of copper sulphate or sodium arsenate. The older masses should be raked out from time to time to allow for the growth of younger plants, but enough should be allowed to remain to satisfy the needs of the fish and other small organisms which naturally feed upon just these forms of plant life.

What effect the aquatic flowering plants have upon fish ponds and lakes the writer does not pretend to know. In some cases at least it may be found beneficial to remove them.

THE SIGNIFICANCE OF ALGAL ORGANISMS IN FISH PONDS

As a result of our own investigations, it seems to the writer, that there are several important reasons why a certain amount of green or blue-green filamentous algae should be allowed a place in fish ponds.

(1). Algae, when in thriving condition, keep the water supersaturated with oxygen. Fish can not live in water in which there is a deficiency of oxygen.

(2). Masses of floating filamentous algae, sometimes termed "blanket-algae", form the natural home of the minute animals upon which some fish species, or developmental stages of others, live. These minute organisms are fed and protected by the algae so that they are able to reproduce abundantly and thus maintain the animal food supply.

Anyone who will examine such floating masses of algae will find them teeming with the larvae of the midgefly and other insects, and with other small animal organisms. Midgefly larvae, as far as is known, feed only upon algae, particularly upon the green algae. Some of them, too, build their cases of algae. It is to be noted that, with the exception of one species, the *midgefly larvae are not plankton feeders.* Apparently those which live on rock or mud surfaces, rake or sweep together small masses of attached unicellular or minute filamentous forms, using both mouth parts and prolegs in the process. They seem to feed continuously on the algae growing about them. On the other hand, the larvae which inhabit masses of floating filamentous algae, either scrape minute unicellular algae from the surface of the larger filamentous plants, or they suck in the protoplasmic contents of the cells of these algae themselves, whenever filaments are broken or bruised. This process the writer has repeatedly observed. For instance, in one case, a *Spirogyra* cell was wounded and the wall broken open. It was immediately discovered by a midgefly larva which proceeded to suck in the whole of the green mass consisting of protoplasm and chlorophyll. The entire digestive tract was discernible through the transparent body of the animal. When first swallowed the chlorophyll mass was bright green; when it reached the stomach portion of the tract it changed at once to a brown color, probably due to the effect of the digestive juices. Dr. Francis E. Lloyd has described in detail the peculiar feeding habits of the microscopic animal, *Vampyrella,* which apparently subsists entirely upon the cell contents of *Spirogyra.*

Observations are available to show that even mature carnivorous fish in the open will now and then take a certain amount of algal food, presumably for the same reason that the carnivorous dog and cat frequently eat grass and the tender leaves of other plants. It may be that all meat eaters, like those under observation, provide themselves with green food as needed, to satisfy, perhaps, a natural craving for vitamin C.

At any rate, it must be conceded that many freshwater fishes consume a considerable amount of algae under certain conditions, and that some of them are entirely vegetarian in their habits. It is generally supposed that there are sufficient microscopic floating (plankton) algae in the water to supply such needs as these, and this is true in regard to one fish, the famous gizzard shad, which Dr. Tiffany studied and of which he said: "The gizzard shad is about the most wonderful tow net that

one could desire to get an estimate of the kinds and proportionate numbers of microscopic algae present in a body of water." But it can be proved by proper investigation that plankton forms do not make up the bulk of the food in most species of vegetarian fish. It is mostly the green filamentous forms, either floating or attached, such as *Oedogonium, Spirogyra, Microspora, Ulothrix, Cladophora* and *Pithophora,* which are found to be present in the digestive tracts of these fishes in considerable quantity.

In this laboratory a study has been made of the food of the young large-mouthed bass and golden shiners, taken from tanks at Fairport, Iowa. Two bass were found which had eaten *Oedogonium* and *Cladophora.* One of these, 58 millimeters in length, had eaten 73 *Oedogonium* plants. Now, it would take hundreds of unicellular forms, such as diatoms or desmids, to make up the bulk of protoplasm contained in the cells of a single *Oedogonium* plant. It must be recognized, then, as a fact, that even the bass, a carnivorous fish, at times feeds upon algae, but whether from hunger, or by accident, we do not know.

The golden shiners, in the investigation mentioned above, when between 45 and 94 millimeters in length, were usually found gorged with masses of such large filamentous green algae as *Oedogonium, Spirogyra, Pithophora* and *Microspora.* On the other hand, the youngest shiners examined, 12 to 22 millimeters in length, proved to be principally animal feeders. Even so, except in the cast of *Bosmina,* the young bass and young shiners did not consume the same species of microscopic animals.

While it is not desirable for a student of algae, unacquainted with the practical details of fish culture, to advise in such a matter, it seems as if it should be possible to arrange the construction of tanks or ponds in such a way that golden shiners might be grown as food for large-mouthed black bass, both kinds of fish being reared in the same pond. The young bass, of course, should all be of about the same size and larger than the shiners. The proper kinds of green algae allowed to grow in the tank, would be consumed by the shiners and thus kept completely under control. The shiners in turn—theoretically—would be eaten by the bass. A normal food chain would thus be established in which the green algae would manufacture food, including vitamins; the shiners eating the algae would convert vegetable food into animal flesh and, for a brief period, store vitamin material supplied by the algae; the bass feeding upon the minnows would receive exactly the natural food for which they are adapted and would therefore require little or no artificial food.

THE PROBLEM OF ALGAL CONTROL

"Polluted" waters are those which are more or less foul because they

contain decaying organic matter. These organic substances may be present in water because of various conditions:

(1). A stream or lake may be polluted by water impregnated with the soluble matter from nearby peat bogs or swamps.

(2). As an after effect of forest or grass fires, followed by a heavy rainfall, potash and other mineral constituents of the ashes may be carried into streams or lakes, thus increasing the alkaline content of the water and contaminating it perhaps for a period of years.

(3). Vegetable matter of any kind on the floor of a body of water —such as a mass of dead leaves, or as leafy aquatics and the larger green algae when killed by copper sulphate—undergoes decomposition, thus causing a decrease in oxygen content with consequent harm to fish life.

(4). The settlement of a country, attended by the gradual accumulation of waste matter from cities, factories and mills, results sooner or later, in the contamination of surrounding bodies of water.

Now, Blue-green Algae use as food certain of the organic substances in such polluted waters. This means that they prefer waters which are foul with decaying organic matter. Therefore, when blue-green algae are found in excess it must be considered as a definite indication that pollution is present.

Sometimes, certain species of Blue-green Algae occurring normally in the invisible plankton of a lake, will suddenly so rapidly increase in numbers as to cause the phenomenon known as "water bloom", when the algae become not only disagreeably visible to the eye, but also objectionable in odor and taste.

It is difficult to discover what the factors are that determine the development of water bloom in any particular body of water. In fact it probably can not always be done. But in Minnesota lakes, for instance, a higher temperature than existed under former conditions of forestation and drainage together with the increase of pollution due to settlement, apparently have much to do with the occurrence of the troublesome blue-green water bloom. It is this condition which causes the surface of lakes to be covered with a—sometimes continuous—layer of material resembling green paint or a thick pea soup. These particular blue-green plankton algae, as said above, indicate that the water in which they are found is polluted.

Now, if the water was initially polluted, is anything gained by adding copper sulphate to kill the algae? Unquestionably it kills the algae, but it does not make the water more pure. Water bloom conditions in a lake are distasteful to bathers. Cattle, horses, and other livestock, compelled to drink such water have been killed, not because the living algae themselves are toxic, but because large masses of decaying plants of any kind, taken into the stomach of an animal, are harmful. Nor, do fish do well in a body of water the surface of which is covered with decaying

blue-green algae, for with the process of decay goes the decrease in oxygen content of the water and this condition often causes the death of fish. The fish may be killed also by the clogging of their gills with the mealy water bloom material. Another thing must be considered; green algae can not thrive and in general do not grow in such contaminated water and thus an important source of oxygen generation is excluded.

From what has been said, it will be seen that if a lake is wanted only for bathing purposes, algae may be legitimately destroyed by using copper sulphate or sodium arsenate. But if fish are wanted, the algae should not be destroyed.

The important thing to consider is that the presence of blue-green algae in general, and water bloom in particular, constitutes an indication of pollution; and that, therefore, killing the algae is only curing the symptom, not the disease.

On the other hand, fish do well in lakes containing pure water, because other conditions are then usually favorable. Some lakes in the subtropical portion of the state of Florida are under observation. They are deep and are fed by springs on the bottom. There is no outlet. These lakes lie exposed to tropical sunshine throughout the months of the year, but blue-green algae are not found in the water. Such a condition as water bloom has never been observed. The lakes are teeming with fish, big and small, and everywhere around the edges schools of very young fishes are seen. At first glance it would appear that no algae are present but closer observation proves that a short green fringe of *Oedogonium* marks the water level on most of the shores of the lake. This food chain is evidently a successful one as the lakes have been observed from time to time during a period of five years.

What would happen if the water in these lakes became polluted? One result would be immediate. The *Oedogonium* plants would disappear and blue-green algae would take their place. Would the young fish accept this very different kind of food? That, we do not know, but the phycologist would predict that the fish would not thrive on the blue-green algae, for the reason that, so far, studies of the digestive tracts of minnows proves that they prefer *filamentous green algae.*

Since fish foods and the feeding of fish is one of the greatest problems faced by fish culturists, would it be amiss to suggest that some sort of a co-operative study of a fish pond be made by a number of experts in various fields, working together? Perhaps the Large-mouthed black bass, Golden Shiner, Filamentous and Plankton algae "association" might provide a good problem at least for the middle west states.

In a pond supplied with cool pure water, common filamentous green algae should be allowed to establish themselves. Later, minnows should be introduced, followed by bass, the latter being of a larger size than

the minnows. The experiment should be carried through to the end of a long season, no artificial food being given, no additional minnows being supplied. Careful records of all conditions and precise counting of fish at different periods would provide data of biological interest and possibly might furnish a clue to successful methods of rearing fish in ponds.

Now, if a chemist, a physicist, a plant physiologist, an animal physiologist, an animal nutrition expert, an algologist, and a fish culturist were to study that pond and its inhabitants in every possible detail, would not some things be found out that might answer a number of the questions which have been asked in this meeting?

One must go to the source of the trouble in order to be able to apply the proper remedial measures that would result in the refilling of our streams and lakes with quantities of strong vigorous fish. Deforestation, forest fires, drainage of large areas of land, and stream pollution, have all played a part in the present deterioration of our native food and game fish resources. The purpose of this paper will have been realized if it be shown that in the re-establishment of the ideal conditions which once prevailed, the scientific investigation of the algae from all sides must play its part.

FISH AND THEIR FOOD

E. A. Birge

Wisconsin Geological and Natural History Survey

The United States Bureau of Fisheries reports that in 1927 Lake Michigan furnished about 24,000,000 pounds of food fish. Since the area of the Lake is about 22,450 square miles, it follows that the Lake provided a little more than 1,000 pounds of food fish per square mile. These are fish in the raw—on the fin, as it were, to be compared with "beef on the hoof". This amount again is about 1.5 pounds per acre of lake surface, including in this all the area, fishable and non-fishable. Lake Erie of a much smaller area furnished about the same amount of fish; but this lake has been notoriously over-fished. We will assume for the time that this is not the case in Lake Michigan and will use its data as a starting point.

This amount—1.5 pounds per acre—does not represent at all the weight of the fish living in the lake, or even the amount that the lake could supply if all fish were equally eatable. It is the available supply of fish suitable for human food under existing social conditions. If suckers were eaten as freely as whitefish the story would be different. But accepting things as they are shall we call this a large production of food or a small one? And, large or small what is it that determines its limits?

The answer to the first question depends a good deal on our point of view. First, it may be said that in production of fish Lake Michigan does not stand especially low or high, considering the size and depth of the lake. A smaller and shallower lake such as Lake Erie may produce a larger amount of fish. For smaller inland lakes no accurate data exist for this country and very few estimates. Professor Pearse estimated that Lake Mendota—to whose food supply we shall refer later—might furnish annually some ten pounds of perch per acre. The total available supply of food fish from this lake would not greatly exceed this estimate, since the perch constitute a very large fraction of the edible fish of the lake. In Europe the fisheries in inland lakes are often rented and are regulated so that there may be a constant supply of food from them. Such lakes in Sweden may produce annually from one pound to eight pounds per acre. In Germany they may rise as high as twelve pounds per acre. In no case, however, is the supply of a different order of size from that which the Great Lakes afford.

Second, our answer will depend on the kind of comparison that we make. Shall we compare the lake with wild land or with cultivated soil? Our Conservation Commission estimates that about 10,000 deer were killed in Wisconsin last fall and that this number is as great as should be permitted. It not unfairly represents the available crop.

A good sized deer may weigh 140 pounds "on the hoof". To be generous we may allow 1,500,000 pounds for the whole crop. We do not know the area over which these deer fed, but it can not be many times less than that of Lake Michigan. We are wholly safe in saying that the lake produces ten times as much food as does the forest, and that from this point of view the lake's performance is a very creditable one.

On the other hand the production of the water is vastly behind that of cultivated land. Wisconsin produces each year about 150,000,000 pounds of butter alone. This weight is a hundred times as great in a concentrated food stuff as is the gross weight of the carcases from which the venison comes. Wisconsin produces annually over 2,500 pounds of butter per square mile, including in those square miles the deer forests, the lakes, the cities, the roads, besides all the pastures and farm lands given to other crops. Clearly the product of the lake is simply "not in it" when compared with that of cultivated land.

On what does this disparity depend and what sets the limit to the production of fish in a lake? Let us first compare the production of fundamental food stuff in water and on land. By far the greater part of this food stuff in the lake consists of minute algae. The size of these is to be stated in thousandths of an inch or at most in hundredths of an inch, and they exist by hundreds of thousands or even millions in a quart of lake water. Thus in spite of small size their combined mass is considerable. We have studied this material from Lake Mendota and we find that the standing crop ranges from about 2200 pounds per acre of surface to about 4600 pounds, with an average of about 3000 pounds. These figures are for the algae as they are present in the lake in the living or recently dead form: when dried they lose about nine-tenths of their weight in water.

So far as chemical analysis can show the facts these algae offer a good and very nutritious food. Of course not all are equally valuable as food and not all are equally palatable to their would-be eaters. They should not be compared with the plants of a cultivated pasture or hay field, but rather with the plants of a prairie, where rosin-weed and similar inedible plants compete with the grass. But after all such deductions it is plain that the standing crop of this fundamental food has a weight of the same order as that of good farm land and that it is in a form probably as available for the animals which are to be supported by it.

This standing crop has much the same size in various lakes, provided that their chemistry is similar and that their physical surroundings are not widely different. Green Lake, Wisconsin, is nearly three times as deep as Lake Mendota, but its standing crop of algae is about the same as that of the shallower lake. Lake Waubesa has less than one-half the depth of Mendota but it also has much the same amount of algae. This general resemblance coupled with considerable minor

variations, is what would be expected, since the production of plants in the lake, like that of grass in the pasture, is primarily a function of the surface.

Before I go further let me call attention to an important difference in the standards which we are using in talking of the quantity of fish and of the food for them. We do not know the size of the standing crop of fish in any lake. All we know is the surplus available as food for us, and we know far too little about that. In the case of the fish food the little that we know relates rather to the standing crop than to the annual available supply which goes directly or indirectly to the fish. But even on this subject a little can be said.

The annual turnover of the fundamental food stuff can only be estimated. It is not like grass which grows on a surface and can be cut and weighed at intervals. New crops are coming on all the time within the upper water and old ones are going out. This is happening at all seasons, most rapidly in summer. A few days—even a few hours—may double the amount of one minute algae while another may be going down as rapidly. The estimate has been made that on the average the crop is renewed every two weeks. This is little better than a guess, but it is at least a conservative one. We are safe in saying that an acre of lake surface produces annually several tons of this fundamental food and that in quantity as well as in quality an acre of lake water is not inferior to a similar area of the land. The limitations on the production of fish do not lie primarily in the quantity of fundamental food stuffs.

These limitations arise out of the fact that the fundamental food is not immediately available for most of the fish. They do not eat algae any more than we eat grass. They are carnivorous and therefore there must be intermediates between this great production of vegetable food by the lake and the dinner table of the fish.

There are two main streams of food, immediately available for fish, which have their source in the algae. These are the minute crustacea of the open water and the animals that live on the bottom, chiefly insect larvae, worms and small snails. The crustacea are well known to you under the name of water-fleas and you know also their importance as a food for young fish. Substantially all fish in early life feed on them and some always continue the habit. There are two main groups of them—the Copepoda and the Cladocera—differing in structure and details of habit but not differing greatly in size or in availability as food for fish. They live together in the same water, they feed on the same food—the fundamental food and its immediate derivatives. Their individual size is large as compared with that of the algae, the largest forms measuring a tenth of an inch.

We can estimate the amount of the standing crop of this important

source of food for the fish. The quantity in Lake Mendota has been placed at about 200 pounds of living material per acre. This weight includes their delicate shells and other indigestible material, just as the weight of the fish with which we started includes fins, scales, bones, and other offal.

There are other and smaller animals which may be considered part of this great stream of fish food. Chief among them are the Rotifers; but their aggregate weight is in general very small as compared with that of the crustacea and we need hardly add to our estimate if we include them also.

Thus a standing crop of fundamental food amounting to 3000 pounds per acre sustains a weight of small crustacea amounting to only about 200 pounds or less than one-tenth as much. The reproduction of the algae is much more rapid than that of the crustacea so that the reason for this great reduction does not come from that side of the life of the lake. It is evident that the fundamental food is used in a very uneconomical way, as is apt to be the case with the processes of nature. An acre of good pasture maintaining a standing crop of a ton and a half of grass would support more than 200 pounds of beef on the hoof.

Part of the answer to the questions raised by this difference between land and water is found in the fact that the algae are scattered through the water instead of being concentrated into a kind of sheet like the grass. These algae the crustacea must strain out of the water or pick them out and either process is a slow and laborious one. You may compare the lake water with its algae to a sort of soup in which the algae represent the noodles. The crustacea strain out the noodles and eat them. But on the average one must strain about 400 gallons of water from Lake Mendota to get an ounce of noodles and that, as you will readily see, constitutes a rather thin soup. A Daphnia or Cyclops must get the algae from about 60,000 times its own weight in water in order to secure its own weight in food. So great is this disparity that some biologists have thought that these crustacea must get much of their nourishment from the organic substances dissolved in the water as well as from the particles of living material. These substances are present in quantities much greater than that of the algae, but we have not been able to find that the crustacea can make use of them.

An interesting result of this way in which the crustacea feed is that in the deeper lakes,—like Green Lake—the crustacea are smaller than they are in the shallower lakes. The food is produced near the surface and is about the same in amount in both types of lake; but in the deep lake it is distributed through a greater volume of water and is correspondingly harder to collect. The soup is thinner, so to speak.

We know something about the reproduction of these crustacea, though

we are very far from knowing all the details of the story. In summer there may be a new generation every two weeks or ten days, or even at shorter intervals; in winter reproduction may nearly cease. In any case the turnover is far slower than that of the algae, but there can hardly be less than ten or a dozen renewals of the crop during the open season. We shall not go far wrong if we estimate that the annual production of crustacea has somewhat the same relation to that of the algae as is borne by the respective standing crops.

It is plain that by far the greater part of the algae escape being eaten by crustacea and that plenty of fundamental food is left to sustain the second stream of intermediates that issues from it. This stream is made up of the animals of the bottom, which are maintained chiefly from the gentle rain of organic material that constantly falls from the water of the lake. Chief among the inhabitants of the bottom ooze are the insect larvae, for whose type we may take the common "blood-worm" —the young of the midge Chironomus. Besides these insects there are also worms of various kinds and less plentifully small snails and clams which may also serve as food for fish. The total weight of the organic material in these organisms in Lake Mendota may amount to 300 pounds per acre, a larger quantity than that of the crustacea. But reproduction is slow in these animals, one, two, or at most four crops a year are all that can be obtained. But the individuals are larger than are the crustacea and they therefore appeal to the appetite of larger fish. Since they live on the bottom they are more closely concentrated and are more readily available as food. Thus while their annual production is smaller than is that of the crustacea, they are probably quite as important as a source of food and a larger fraction of them is eaten than is thus consumed from the crustacea.

Thus in Lake Mendota the standing crop of fundamental food maintains a total of about one-sixth of its weight in food directly useful to the fish. Only so small a proportion is maintained in spite of the fact that the algae reproduce far more rapidly than the crustacea or insects, so that the disparity in annual production is even greater than that in the standing crop.

We do not know the standing crop of fish in any lake and we therefore can not tell how it compares with that of the intermediates on which it depends. The fish themselves constitute a complex community of eaters and eaten, but in the end their total amount is determined by the quantity of food available from outside of their own community. We may estimate that just as the standing crop of fundamental food stuffs may be stated in tons per acre, and that of the intermediates in hundredweights, so the quantity of fish per acre is to be expressed in pounds rather than in any larger unit—unless you choose to adopt the English unit of the "stone" of 14 pounds. So also of the annual produc-

tion—tons per acre of algae, hundredweights of crustacea and insects, and pounds of fish. At every stage the supply of food is wastefully applied and produces results very small in proportion to its theoretical possibility.

Plainly the reduction in results is greater as the number of stages increases through which the food passes before reaching that stage in which we as consumers are directly interested. The fundamental food goes through at least two stages of animal life—usually more—before it reaches the form that we eat. When we raise beef in a pasture the grass is converted into beef at one stage. But suppose we ate carnivorous animals instead of herbivores. Suppose that the grass fed only rabbits and that we ate only the wolves that fed on the rabbits. Clearly the production of meat per acre would be very small under such conditions. Such a supposition is very far from adequately representing the number or the complexity of the stages that intervene between the algae of a lake and the lake trout or bass or muscallonge which we want to catch. At every stage there is a great reduction in the quantity of living substance as compared with that on which it feeds. Eaters and eaten constitute a sort of pyramid whose section diminishes rapidly as its several stages are built up. As eaters of fish we are interested in the surplusage of the apex of the pyramid and we should not be surprised that it is very small in comparison to the broad base which supports the whole structure.

Let me add one practical suggestion to this rambling account of the succession of food and feeders in a lake. Most of us are deeply interested in the supply of game fish—that is, in the larger and older individuals of those species of fish which are furthest removed from the fundamental food stuffs. Now the nearer an organism is in size and habits to the fundamental food, or failing that, to the intermediates, the larger its possible quantity. The converse also holds, that the further the distance from the fundamental food the smaller the possible quantity. In other words the weight of the game fish in a lake, which have reached the legal size, is necessarily very small. It would be quite negligible if stated in pounds per acre and would be only a small fraction of the total weight of the fish in the lake. The weight of smaller fish, like minnows and perch, constitutes by far the larger part of the fish population. Only a few big muscallonge or even big bass are possible in a small lake and the supply is very slowly renewed. Thus an amount of fishing which does not at all sensibly reduce the total weight of fish in a lake may very seriously alter its character. The death of big predaceous fishes gives a chance for the smaller fish on which they feed to grow and to multiply, and this they are quite ready to do. The perch are always on hand to occupy any vacant places in the fish community, making up by numbers for small size. Catching

out the bigger game fish more rapidly than they grow up does not reduce the total weight of fish supported by the fundamental food stuffs, but that weight may be in perch and suckers rather than in game fish of legal size.

The maintenance of a supply of game fish in a small lake offers problems of a different kind from those presented by the supply of commercial fish in the Great Lakes. The continuance of commercial fisheries depends on the presence of schools of edible fish of a fair average individual size, to be caught in great numbers by nets, etc. Good fishing for sport calls for the continued presence in a lake of a relatively few large individuals of the desired species, which are to be caught singly. They must be larger than the average adult. They are not caught primarily for food but for sport and as a basis for stories. A dozen half-pound bass are by no means an equivalent for one three-pounder from this point of view. But these large individuals are few in number: they are old and have come to full size very slowly. It is easy to catch them and very hard to replace them in the presence of the vigorous competition for food that goes on in a lake. And as yet little thought and less study have been given to the needs of this specific form of conservation of fish resources.

THE AERATION OF HATCHERY WATER SUPPLIES AND THE INCIDENCE OF DISEASE

By Emmeline Moore

Investigator in Fish Culture, Director of the Survey

Many of the older hatchery sites were chosen with the two requirements of ***volume*** and ***temperature*** as the prime essentials of a suitable water supply. Through years of experience a third factor, that of proper aeration or oxygenation, has come to be regarded as indispensable in efficient hatchery practice. In relation to the latter essential, I wish to record some observations on the incidence of disease in three of the older hatcheries in my State where the gaseous conditions of the water supply are apparently a limiting factor in the output.

The water supply at the Caledonia hatchery possesses the important requirements of large volume and suitable temperature but it is deficient in oxygen. The supply is derived from springs in a limestone region and this in itself limits the amount of oxygen that water will hold or can acquire by artificial means of aeration. At the Bath hatchery the physical conditions surrounding the water supply are similar, that is, the springs arise from a limestone region and the oxygen supply is likewise low.

The chemical analysis of the Caledonia hatchery waters is shown in table 1. It is seen that the water at the source contains 2.0 parts oxygen per million, 17.7 per cent of saturation at 49.5° Fahr. After traversing the stream bed nearly a mile and entering a series of pools richly provided with vegetation, the oxygen supply is raised to 4.4 parts per million, saturation 38 per cent at the entrance to the hatchery. At the exit from the hatchery, the oxygen is raised to 7.0 parts per million with a saturation of 62.3 per cent.

The tabulation showing the chemical analysis at the Bath hatchery is not reproduced in this paper but may be referred to in the publication of the Transactions, Volume 52, 1922. Suffice to say that the oxygen at the source of the supply is 1.71 parts per million with 15 per cent saturation at a temperature of 53.6° Fahr. The water after passing through an aeration pond with fountain registered at the head trough 2.10 parts oxygen per million with a saturation per cent of 18.5, temperature 48.2° Fahr. The total hardness by the soap method is 190.

At the Caledonia hatchery it has become increasingly difficult to rear brook trout fingerlings because of the onset of octomitiasis in the early fingerling stages. Heavy mortality due to this disease occurs also annually at the Bath hatchery but the survivors, despite the low oxygen content, attain a splendid growth. In other hatcheries in the State where the oxygen content is high, as e.g. 9-10 p.p.m., mortality due to

octomitus has to date been low. I cite these instances because it is important to know the mortality cause under similar conditions of low oxygen supply elsewhere and I hope we may have papers on this subject in the future.

At the Chautauqua hatchery where the source of supply is from artesian wells, the gaseous relations are of a different character as shown in table 2. Here the water supply contains an excess or supersaturation of nitrogen. The effects of such excess is to produce the well known gas disease described by Marsh and Gorham in their treatise "The Gas Disease in Fishes", Report of the United States Fisheries Commission for 1905. For years this malady afflicted the fingerling trout at this hatchery until a simple device of deaeration at the head of each trough was added to dissipate the excess of nitrogen. As a matter of record I may say I have not found octomitus present in this hatchery.

TABLE 1.—CHEMICAL ANALYSIS OF CALEDONIA HATCHERY WATERS*

Remarks	Date	Temp. of Water, Degrees		Dissolved Oxygen		Methyl orange alkalinity p.p.m. calcium carbonate	Carbon dioxide parts per million	pH
		Fahr.	Cent.	Parts per million	Per cent of saturation			
At source, point A (see below)	Sept. 8	49.5	9.7	2.7	23.9	204.0	12.1	7.4
At source, point B (see below)	Sept. 8	49.5	9.7	2.0	17.7	196.0	12.6	7.4
Water entering hatchery flume	Aug. 25	49.1	9.5	4.4	38.9	196.0	10.1	7.5
Water in trough (indoors)	Aug. 25	49.6	9.8	6.0	53.4	196.0	8.1	7.7
At exit from entire hatchery	Aug. 25	49.6	9.8	7.0	62.3	196.0	8.1	7.7

The water supplying Caledonia hatchery comes chiefly from large springs about one mile away. Two streams leave the scene of the springs, uniting before reaching the hatchery. The smaller of these, designated B, is probably entirely spring-fed, whereas the larger, designated A, receives a certain amount of surface drainage.

*From chemical data of F. E. Wagner in the report of the Genesee River System, supplemental to annual report of New York State Conservation Department, 1926.

TABLE 2
CHEMICAL ANALYSIS OF CHATAUQUA HATCHERY WATER SUPPLY AT BEMUS POINT, N. Y.*

	Oxygen	CO_2	Methane	Nitrogen	Excess Nitrogen
'A'	6.6	nil	nil	19.9	4.93
'E'	7.1	nil	nil	22.3	7.53

'A' and 'E' represent the wells.

*From the chemical data submitted by N. L. Cutler, in files of New York State Conservation Department.

CONTRIBUTIONS OF THE BIOLOGICAL SURVEY TO PROGRESS IN THE STUDY OF FISH DISEASES

By Dr. C. M. McCay

Dr. McCay: I chiefly wish to present a series of slides dealing with fish blood because I believe it affords rich opportunities in the field of fish pathology and fish diseases. For more than twenty years one of the best methods in the medical profession for diagnosis of disease has been the analysis of the blood. We have been slow to use blood for diagnosis of fish diseases, evidently because the blood is difficult to obtain and because it clots very rapidly.

The Biological Survey has an unusual opportunity for making studies of the blood. Most universities and zoological laboratories do not have collection facilities. They have limited field forces and limited opportunities for collecting. On the other hand, most men who are in practical contact with the rearing of fish have splendid opportunities for obtaining specimens. The Biological Survey, therefore, can provide useful information that will never be obtained if we depend upon the university laboratories.

The blood picture of the normal fish is extremely variable, and there are enormous individual variations. However, we get fairly uniform analyses for large groups.

(Showed slides of fish blood.)

PARASITES OF BAIT MINNOWS

R. V. Bangham

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During the past two summers bait dealers in Columbus and other cities report serious losses to the bait minnows held in their tanks. This report is based on a short study conducted for the Ohio Division of Fish and Game during the latter part of August 1928. Some data are included on parasites of bait minnows as a result of my studies on fish parasites with the Co-operative Biological Survey of Lake Erie.

The parasites attacking bait minnows in the dealers' tanks caused considerable economic loss due to the increasing difficulty in obtaining bait minnows at this season, and the recent State regulation limiting the number held at any one time. The minnows for the Columbus dealers were being obtained from many sources and all seemed to be equally affected after they had been in the tanks at the bait stores from 36 to 48 hours. Some of the minnows came from streams in Knox county, others from small cool streams in Delaware county. In almost every case they were hauled 20-30 miles to the bait stores. The water was kept cool and there was no appearance of any diseased condition when the minnows were brought in, although later examination showed that certain minnows did carry in parasites.

These losses and the distress to the minnows in the tanks were attributed by the dealers to the city water, but this was not found to be the cause. Fish of the goldfish dealers and the fish at the Fisheries Building at the State Fair grounds were in the city water. They were in splendid condition.

At one bait store there was a large tank of minnows obtained two days before from small streams in Knox county. Nearly all of the minnows were in bad condition. There were large white areas where the skin had sloughed off. The dorsal fin was usually affected. There was a silvery sheen over the heads of many of these fish and most of them had white and frayed tails. There was an increased mucus secretion over the bodies of the fish. Many of the sick minnows were sluggish and kept at the bottom until nearly dead. When too weak to longer hold to the bottom, they came to the top, turned over on their sides and died. Large areas of skin had come off and often the tail and dorsal were almost completely destroyed.

The minnows that do not usually hold up well died first in large numbers. The first to die were the red-sided dace (*Leuciscus elongatus*) and common shiner (*Notropis cornutus*). The stone-roller (*Campostoma anomalum*), river chub (*Nocomis biguttatus*), blunt-nosed minnow (*Hyborhynchus notatus*), horned dace (*Semotilus atromaculatus*), and the young of the common sucker (*Catostomus commersonnii*) held

up for a longer time in the tanks, but were badly affected and many were lost.

Several hundred minnows were obtained from several bait dealers on various dates and examined. The type and course of the infestation was quite similar at all places visited. There was a mixed infestation of two species of Infusoria—*Cyclochaeta Domerguei* Wallengren and *Chilodon cyprini* Moroff. The first is the larger form and belongs to the family Vorticellidae. It is without a stalk, and has a disc-shaped form with a band of cilia with short, erect bristles outside the posterior girdle of cilia. There is a row of hooks in an inner ventral ring which attacks the skin of the host. This form is about 125 microns in diameter. These forms were easy to see as they actively moved about on the slide which contained scrapings from infested fish.

Three years ago at the Piqua hatchery a heavy infestation of this form was found on the young of large-mouthed bass (*Aplites salmoides*). During the past summer a mixed infestation of Cyclochaeta and Chilodon was again observed on the young large-mouthed bass at this hatchery. At the time of the largest losses the water supply was low due to a break in a reservoir above. When the normal water flow was restored the degree of infestation was considerably lessened.

The Chilodon were mainly found embedded in the skin and mucus. This parasite is a hypotrichous ciliate about 70 microns long and 40 microns broad. Its dorsal surface is convex and ventral surface flattened. It is almost kidney-shaped in outline, but the anterior end is broader than the posterior end. The whole of the ventral surface is covered with cilia, as also the margins of the dorsal surface. Towards the anterior end of the ventral surface is the cytostome leading to a straight or slightly curved oesophagus, which is supported by longitudinal bars representing thickenings through the cytoplasm. There is an ovoid macronucleus and a small micronucleus. The skin was very heavily infested with this form. They did not move about actively, but were embedded in the mucus and surface of the skin.

Another ciliate parasitic in the skin of the fish and often causing serious trouble to all confined fish is *Ichthyophthirius multifiliis* (Fouquet). The ciliate fixes itself to the skin and gradually becomes embedded in the epidermis. As it increases in size a tiny, white pustule is produced. When the fish are heavily infected the whole body is covered with these tiny, white spots, the gills become involved and the health of the fish is seriously impaired.

The minnows in the bait stores did not have this parasite when examined, but the lake shiner (*Notropis atherinoides*) and young goldfish (*Carassius auratus*), used as food for adult bass, were found infested as were the adults of several species of fish used as breeders in the hatchery at London.

Dr. John E. Guberlet of the University of Washington in his publication in 1926: "Ecto-parasitic Infusoria Attacking Fish of the Northwest," [1] reports the result of his studies of these three species of parasites with special reference to the damage done to hatchery fish. He finds that Chilodon multiplies very much more rapidly in warm water, while Cyclochaeta affects fish to a much greater extent in cooler weather. This was borne out by my findings on the minnows from the bait dealers' tanks. While there were very large numbers of Chilodon, the Cyclochaeta were rather scarce.

Certain species of fish seemed to be carrying Chilodon and Cyclochaeta into the tanks. Both of these parasites were found on the stone-rollers and common suckers when they were first brought in from the streams. If such is the case, these fish should be discarded by bait collectors. All nets, utensils, tanks, etc., should be thoroughly cleansed and disinfected at frequent intervals in order to control the disease. Many of the difficulties resulted from failure to use any sanitary measures.

As a result of his experiments on the control of Chilodon and Cyclochaeta, Guberlet recommends that the fish be immersed in a 2½% salt solution for 20 to 30 minutes. I found the fish held up much better if the salt solution was cooled. When scrapings from treated fish were examined most of the Cyclochaeta were dead, but several living Chilodon were found in the mucus. It was quite difficult to conduct tests at the bait dealers' stores as the fish were often sold out of my control tanks, or the water was turned off at night. The results on control are not conclusive, but I soon expect to continue under better conditions for experimental work.

No internal parasites were found in the minnows which cause serious trouble. Twenty-five species of minnows from Lake Erie have been examined for parasites. Of these, the parasites of seven species of fish most likely to be used as bait minnows will be discussed. These are: golden shiner (*Notemigonus crysoleucas*), (*Notropis v. volucellus*), spot-tail minnow (*Notropis hudsonius*), steel-colored minnow (*Notropis w. whipplii*), lake shiner (*Notropis atherinoides*), blunt-nose minnow (*Hyborhynchus notatus*), and log perch (*Percina caprodes*). No internal parasites were found in the golden shiner. It feeds quite largely on plant food and no parasites have been found in ten individuals examined.

With this exception intestinal flukes belonging to the genus Allocreadium have been found in some individuals of all the species of minnows mentioned. The same is also true for the nematode belonging to the genus Camallanus. The spot-tail and steel-colored minnow often harbor from 1 to 5 individuals of the larval fluke Ligula sp. in their body cavities. Spot-tail minnows from some regions have 100% infestation. Most of these minnows have a few encysted flukes belonging to the family Strigeidae in the liver and mesenteries.

(1) Univ. of Wash. Pub., Vol. 2, No. 1, pp. 1-16.

Larval forms which may reach the adult stage in fish which eat these minnows were found in several of these species. ***Proteocephalus ambloplitis*** larvae were found encysted in ***Notropis atherinoides***. Another larval ***Proteocephalus sp.*** was found in the intestines of ***N. atherinoides*** and in ***P. caprodes***. Larval ***Bothriocephalus sp.*** were found in the intestines of several ***N. atherinoides***. Encysted acanthocephala, ***Echinorhynchus thecatus*** were found in ***P. caprodes*** and in ***H. notatus***. Of course these parasites of bait minnows would be of no significance if the fish were caught, but sometimes the fish steals the bait and escapes.

Many of these forms as well as some others may be used as forage minnows at the hatcheries and there is a chance for certain of these parasites to become established in the hatchery fish.

In one hatchery we were able to keep young large- and small-mouthed bass practically free from parasites. When they were last examined they were 15 months old and measured from 9 to 12 inches in length. When they were from 1 to 1½ inches long they were fed ground carp and goldfish. This was continued until the present time. The only live fish used for food were young gizzard shad (Dorosoma cepedianum). This is a species usually free from parasites.

PROPAGATION OF MUSKELLUNGE

B. O. Webster

Madison, Wisconsin

This very important branch of fish culture has been carried on by the State of Wisconsin for a considerable number of years with varying success from year to year depending largely upon the weather conditions. The methods employed in securing breeders have been similar to those used in this state for walleyed pike. Hoop nets are placed in favorable spawning grounds and at a time shortly after the ice goes out we have been able to catch sometimes quite a number of large fish and at other times very few, the catch largely depending on a favorable spring season. We find that the spawning ground of muskellunge is usually in a place where there appears to be a very large amount of decayed vegetable matter. The very best spawning ground that we know of is found in Carrol Lake near the city of Minocqua. It is possible over this bed of decayed vegetable matter to run a 35-foot pole down into the bottom with the hands which makes a rather difficult place in which to set nets so that they will remain fixed during the windy part of the season.

The taking of the muskellunge eggs is very similar to the method used for other kinds but it has been our experience that the muskellunge eggs must be handled very carefully or very poor results are obtained. In fact while talking with Mr. Miller, who has charge of the muskellunge propagation in the State of New York, after I had described our method, he informed me that we handled them too carefully. We find that a breeding ground for these fish must be in close proximity to the hatchery and that after the eggs are taken and fertilized it is advisable to leave them suspended over night in a vessel of water to insure proper water hardening before they are placed in the jars. It is our habit to see that these eggs are gotten into the hatchery without any jarring which necessitates the actual carrying of the eggs in pails by hand to avoid this possibility.

We transfer them to the hatching jars by first filling the jar with water and then carefully pouring in the eggs so that they fall into the water and do not hit the jar. They are then placed in a common whitefish battery and the regular battery process is gone through with to hatch them out. It has also been our experience that about 50% of the eggs that we collect are hatched out. They are run in the jars in the usual way until just before the little fish appear when they are taken out of the jar and permitted to hatch on trays. The fish when hatched in the jars do not swim out as pike and whitefish do. They

remain at the bottom of the jar and hence we believe that it is much better to place them on trays for hatching. The fry are then held on the trays until a few days before the food sac is absorbed when the larger number are planted in nearby lakes adapted to their special requirements.

Up to the present time it has been the practice to plant muskellunge fry in the lakes from which the eggs are taken. About three years ago it was suggested that we make an effort to raise some of the muskellunge to fingerling sizes before they were planted. In preparation for the reception of these young fish, five ponds at our Woodruff hatchery were thoroughly cleaned out of all kinds of fish life and as much plant life as it was possible to remove. Every effort was made to have the ponds perfectly clean when the water was raised and the fish were placed in them. Our first year's experience was about as follows: We planted into these ponds about 20,000 muskellunge fry and the ponds were supplied with crustacea gathered from nearby lakes. Careful watch was kept to prevent the fish being taken by birds. After they reached the stage requiring small fish as food, seining of the nearby lakes and streams was begun and continued until the fish were planted in October.

The muskellunge were planted in the ponds in May and when they were taken out about the middle of October they had grown to a length of about 8 inches. Our first year's experience, however, was not very successful as we were only able to harvest 110 fish 8-10 inches long from the 5 ponds in which 20,000 had been placed. This plan has been carried out for three years with about the same number of fish having been placed in the ponds each season. Last year we were able to distribute about 17,000 and this year the number was between five and six hundred. Thus far we do not feel that any very great advance has been made in the raising of muskellunge to fingerling size but we do feel that we should continue to experiment along this line in the hope of finding some means of raising a larger number and a higher percentage of those started with.

It is my opinion and this was supported by Mr. Miller of New York that on account of the fact that the muskellunge is a slow moving fish, the mortality among the young is greater than occurs in the case of other lake fishes.

TO ASSIST NATURAL PROPAGATION IN INLAND LAKES

B. O. WEBSTER

Madison, Wisconsin

At one of the former meetings of the American Fisheries Society the minutes of which I was reading, I noticed the following question propounded to the Society by Mr. Charles Burnham of Louisville, Kentucky: "Has anyone here ever made any effort to assist natural propagation in inland lakes?" The question was not given very much consideration as I noticed in the minutes of the meeting someone immediately commenced discussing some other subject but Mr. John W. Titcomb was impressed and stated subsequently that he believed Mr. Burnham had brought to the attention of the Society one of the most important questions that had come before it. It impressed me very much and I gave it considerable thought. Very shortly after this there came to my attention a letter from a man in Waukesha, Wisconsin, who used to live in Norway and he related a story that was very interesting to me. He said that when he was a boy his father trimmed a good sized orchard on the shore of a lake and he and one of the boys took the brush out into the lake and staked it down into a large pile in the bay not far from shore. They discovered that large quantities of small fish soon inhabited the brush pile and it soon became known to all the people living in the community that good fishing was established by the presence of the brush break. He thought that the brush break, as they call them, was the means of creating good fishing in the lakes and expressed himself in this way, that the larger fish in the lake gathered around outside of the brush break waiting for the little ones to come out that they might feed on them. By fishing near one of the brush breaks, it was always possible to get a nice mess of fish.

We, of course, all know that brush piles in bass ponds are beneficial and I believe that these brush breaks when properly established in lakes will be a great protection to the natural reproduction of various kinds of small fish that are found in our inland lakes. They can be built in such a way that the ice will not disturb them and of course should be located in a selected place that would not interfere with spawning beds. In their construction grass, leaves and sods can be used also. I believe it would be very beneficial to one of these brush breaks to plant several orange boxes of horse manure, as we all know that great quantities of aquatic life are germinated from the presence of such fertilizer.

Mr. Hoard who publishes a paper in Ft. Atkinson, Wisconsin, has

been very much interested in assisting natural reproduction and has carried out this idea in a small way by establishing bundles of brush along the shore of a lake in front of his cottage. He also has suggested that small log houses might be made and placed in the lakes for the protection of small fish. I think, however, that the brush break is a suggestion that can be made to those who are interested in assisting natural reproduction of fish in lakes.

XXIV.—Discussion

MR. WEBSTER: We undertook to rear the little muskellunge this spring in trout rearing tanks, 14 x 3 x 1½ feet. The tanks were supplied with large quantities of the crustacea gathered from the lakes around the hatchery. We soon found, however, that the fish in the tanks absolutely refused to take anything but the very softest kind of bugs, and we were unsuccessful in rearing any muskellunge in tanks. After they had remained about a month in the tank they were planted in a nearby lake. I believe that the only way that we are going to have a really successful operation in raising muskellunge to fingerling size will be to follow the plan that Mr. Albert has used with wall-eyed pike; namely: clean out a fair sized lake that will furnish sufficient food for these fish and plant in it all the fish which are hatched. It is the method employed in New York State, all the fish that are hatched being planted in Chautauqua Lake. I believe, however, there is a way that these fish can be handled, and we are going to try to find it.

MR. THADDEUS SURBER (Minnesota): My experience is limited to the production of muskellunge fry. Six years ago I took a trip down to the Bemus Point hatchery on Lake Chautauqua and spent several days there in order to become familiar with the modus operandi of taking muskellunge eggs. I went out with the fishermen or hatchery employees, saw them take the muskellunge eggs, assisted them in order to get my hand in, and saw them handle the eggs at the hatchery. Apparently we have delayed matters too long in Minnesota. Muskellunge cannot be obtained in sufficient numbers to justify our making an attempt at propagation. Last year we were able to obtain only two or three muskellunge in a bay in which they were known to exist in great numbers fifteen to eighteen years ago. The year before we obtained in the neighborhood of three to four thousand eggs.

I note that Mr. Webster has been a little more successful in handling his eggs, probably due to greater experience. Our hatch has not been over about thirty-five per cent of the eggs, under the best conditions. We have obtained them three springs now, but in limited numbers. They are exceedingly difficult to handle in the jars in that they revolve slowly on account of their weight and softness, and apparently never become hard like pike eggs. I hope Mr. Webster will continue his investigations to a point where he can produce fingerlings. I agree with him that the introduction of a few fingerlings into a lake where they could be protected until maturity, and then their offspring transferred to other lakes would be the most successful means of distribution.

I do not recommend their introduction into any lake not already inhabited by them.

Mr. G. N. Mannfeld (Indiana): I am much interested in that part of Mr. Webster's paper which relates to the brush piles and submerged logs. In our State we had at one time a river that perhaps you have all heard of, the Kankakee, which has been largely ditched. This river was full of logs and submerged obstructions. It was formerly a wonderful river for fishing, for bass, wall-eyed pike, crappie, and all game fish, but today is nothing but a series of drainage ditches with no obstructions or hiding places for fish. It has made a very great difference in the recreational facilities available to our people. Without obstructions in our streams the larger fish will not stay.

FISH CULTURE IN LOUISIANA

By Percy Viosca, Jr.

Director of Fisheries, Louisiana Department of Conservation

Last year, in her famous banquet speech, Dr. Emmeline Moore effectively outlined the three ages in the history of fish culture. In the State of Louisiana, as elsewhere, fish culture went through these same three periods of development. During the first period, the experimental period or age of migration, cold water species such as the rainbow trout and the northern small-mouthed bass migrated via the fish car far from their native home into the State of Louisiana; but, as we have later learned, only to serve as tempting morsels for our more voracious native species.

During the second period, namely that in which the practical and scientific aspects of fish culture merge, there arose, as a result of the confusion and diffusion, our wonderful Beechwood Fish Hatchery, a project which might easily be considered the last word in warm water fish hatcheries. Fry in large numbers were hatched and planted throughout the State in proportion to political pressure, regardless of whether or not there was a life expectancy for them, and perhaps little did our political ancestors care as long as the public was fooled into believing that due to their efforts the frying pan would not be relegated to the scrap heap.

Next, came the age of thrills, the age, in which to be a fish culturist, one must be both an "ologist" and an "onomist." Since taking charge of the Biological Research conducted by the Louisiana Department of Conservation, I can assure you there have been thrills aplenty. For example: there was the discovery of the southern small-mouthed bass, (wrongly christened the Kentucky bass), in the spring-fed streams of Louisiana; a small-mouth, camouflaged in the pattern of the large-mouth in order to conceal himself from the ichthyological taxonomist or maybe perhaps from the taxonomic ichthyologist. By means of a ruler and scale counts we have demonstrated this to be the most voracious species within the confines of our State, yet, from the beginning, our fish culturists had been feeding those native small-mouths with various and sundry fry and fingerlings of the large-mouth, a sluggish-water species which cannot exist after breakfast time in the same waters as the new small-mouth.

During this age of scientific curiosity, we are learning that many factors, among them the cannibalistic habits of game fish, the presence of other predaceous species, the scarcity of a natural food supply, pollution, diseases, or conditions detrimental solely to the development

of young fish, may nullify the good deeds of pork barrel politicians, and their failure may be rectified only after thorough scientific study of the ecology of our aquatic environments. The "ologist" clan are now in the ascendency, and with the aid of high sounding terminology, they can at last mystify the politicians and thus bluff them into believing that "ologists" alone can outline a safe and sane fish culture policy.

In all seriousness, I will now outline Louisiana's present fish culture policy. First, we have gotten away entirely from the planting of fry and we are getting away from the planting of fingerlings as fast as that is practicable. We are raising all of the important native game fishes and no foreigners, and are planting each species only in such waters as are suitable for their development. Owing to the almost prohibitive cost of transporting adult fish, Louisiana is getting away from the plan of a central culture station and has entered a period of decentralization. Two additional fish culture stations have been recently constructed, each upon a beautiful lake and for the sole and only purpose of stocking the lakes in question without the handling of a single fish by the tin-can method. Other projects of this type are at present being formulated. Our central fish hatchery has been enlarged and converted into a fish rearing plant, in reality a demonstration fish farm to serve as an experimental station and model for other public and private enterprises.

Our new projects are in reality rearing plants and hatcheries combined in a novel way. The unit pond adopted for this plan averages about twelve acres, and varies in depth from zero to 6 feet or more. Instead of trying to imitate the purely artificial culture necessary for the rearing of trout under concentrated conditions, we have endeavored to copy from nature, those features most favorable to the production of pond fishes. In order to produce a maximum amount of shore-line, the areas are scraped into a series of hills and furrows, the hills rising above the high water level. These hills run in a north and south direction to produce the maximum amount of natural shade and are planted in willows. The submerged areas are planted with those aquatic plants found growing most abundantly in natural waters where pond fishes thrive. We find Saggitaria, Vallisneria and Potamogeton pusillus very desirable.

About 10 per cent of the total pond, an area with both deep and shallow water, is set aside as the hatchery or brood pen. This is segregated from the remainder of the pond, the rearing pond proper, by means of levees and a fence of one-inch mesh poultry netting, the latter rising three feet above the water level. In these pens the adult fish are placed in the early spring and resort to nesting almost immediately.

The ponds before filling are fertilized with about 1,000 lbs. of stable manure to the acre. In addition to the original fertilization, at convenient intervals, usually about twice a week, the ponds are refertilized with waste fish and fish dressings secured from the commercial seiners. Cyclops, Cypris, Ceriodaphnia, Hyalalla, and other native small crustaceans are introduced at the time the water is let in, and in a short time an astounding culture of these food organisms as well as Chironomid and other insect larvae is developed throughout the entire pond. When the young fish hatch, they find a super-abundance of live food of a highly desirable type available within easy reach. Instead of transferring the fry from the hatchery proper to the rearing pond, by artificial methods, they simply follow the shore-line of their own accord and escape through the poultry netting into the main pond where they can be seen in schools of thousands along the shore-line and amongst the vegetation. At the time the hatchery is stocked with the brood fish, the main rearing pond is stocked with top water minnows, gizzard shad, lake shiners, *crayfish and other food forms available in the localities of the station. All of these organisms are found to propagate rapidly and their young soon become available as food for the growing fingerlings. Our object is to rear in the same area, as nature herself does, a series of food organisms of the proper size, kind and quantity to produce a maximum growth. Thus cannibalism is virtually eliminated yet without resort to artificial feeding of the game fish themselves.

The purpose of the plant is not primarily to raise a given number of fish per acre, but to produce as great a poundage per acre of large size fish as is practicable under the most ideal natural conditions, artificially produced. Upon reaching maturity, the fish are released directly by gravity flow into the adjacent lakes. This, of course, is not the case at our main hatchery where they are transported in the usual way to the waters to be stocked throughout the State. In the case of our Lake St. John Hatchery, where most progress was made and where conditions approached the ideal aimed at, the results were simply astounding and far exceeded our fondest hopes during the first year. Indeed they were quite comparable to trout propagation in regard to the number and poundage per acre produced. Sample seine hauls were made in different parts of the pond before the fish were released and by means of these counts, and also estimates based on the number of fish per cubic foot of water, we arrived at the almost unbelievable figure of two and one-half million fish. The large majority were sunfish, our official estimate being approximately 2,000,000 sunfish, 400,-

* Dorosoma, Signalosa and Abramis.

000 large-mouth black bass and nearly 100,000 crappie and white bass. This would indicate a production of over 200,000 fish to the acre, the pond being 12 acres in area.

An important feature of this method of culture is that these fish are not fry, but fish ranging from fingerlings to adult, and mostly capable of protecting themselves from natural enemies. The young bass ranged in size from 4 to 13 inches and from one ounce to 1¼ pounds. As the brood stock was only placed in the pond on April 19, 1928, and the pond drawn on January 24, 1929, none of these fish were over 9 months old. A 1¼ pound bass at 9 months old is nothing short of remarkable. The brood bass, which averaged 1 pound per fish in April, averaged over 3 pounds, or a gain of over 2 pounds per fish in 9 months. Several species of sunfish constituted the large majority of the count by number, although only a minority by weight. These mostly ranged from one to three inches, although some were four inches. The hatching and growth of white bass in captivity is in itself a feat. Some specimens of this species, a half-pound in weight, were produced in 9 months.

Not only in regard to the number and size were the results outstanding, but in the total poundage produced. Our estimates of the weight increase in the whole 12 acres was close to 10,000 pounds or nearly 800 pounds per acre of water during the first season. Based upon these results, I am of the opinion that as much as a ton of game fish per acre per year could be produced by such methods of cultivation if carried beyond the first year.

The plan is so simple that no expert is needed to supervise a project. It is so inexpensive that no county or sportsmen's league chapter can afford to be without one. The fish do their own feeding from birth, it being only necessary to provide fertilizers, a proper growth of plant life, the animal food organisms, and the proper amount and kind of brood stock. The Lake St. John project referred to was built at a cost of $3,500.

Another feature of the Lake St. John project is that it is self-supporting and was built without state appropriation. This and a number of other important game fish lakes had been closed to commercial seining for a number of years. For some time we have been advocating the leasing of the commercial fishing rights to responsible fishermen who will have their privilege revoked whenever their operations are destructive to game fish. Under the plan a revenue of two cents per pound is paid into a police jury fund to be used solely for the purpose of improving the lake in question. Concordia Parish, in which Lake St. John is situated, was the first to seize the opportunity and collected

$8,300.00 royalty in a little less than 10 months' commercial fishing. This was used to build and operate the project and pay a special warden, as well as provide other needed improvements. Instead of the seining operations being harmful, aside from providing a revenue, over 400,000 pounds of coarse and marketable fish were removed from the lake in about 9 months, most of these being enemies or competitors of the game fish. This amounts to 200 pounds per acre of open water in an area of about three square miles, a remarkable production for natural waters. Not only were about 30 men given productive employment just after the most destructive flood in history, but over $40,000 of New York money was circulated in the small settlement along the lake. The plan is spreading like wildfire and is being put into practice on important lakes throughout the State. It is settling the war between the angler and the commercial fisherman in a way immensely profitable to both, and we are about to witness a duplication of the Lake St. John achievement on many lakes throughout the State.

Having learned that Louisiana's early day fish cultural practices were a poor business investment when considered in terms of increased production in our waters, we believe, after considering the first year's results of our decentralization plan, that we are entering a new era of fish culture practice. The cost of producing and planting fish, including interest on investment was about 10 cents per fish at our Beechwood Hatchery, and only fry and fingerlings were planted. Under the new plan the cost figured on the same basis has been reduced to about 10 cents per hundred, and the fish planted range from fingerlings to adult and are capable of coping with competitors and natural enemies. These latter incidentally are being thinned out, at a rate sufficient to maintain in our bass waters, a balance of nature favorable to the game fish.

Even with these gratifying results before us, we do not expect these present-day fish cultural operations to produce the most economical results in every instance. Shortage of the natural food supply, natural or artificial stream pollution, which either prevents the healthy growth and development of fish or causes these fish to migrate from the streams into which they have been placed into other waters, disease brought on by adverse conditions, or other factors may mitigate against us.

We are coming to learn that fish hatchery practices and fish culture are only two links in the steps necessary to produce fish in our waters, and that conditions in the waters themselves must be bettered if these fish are to have an ample food supply and other favorable conditions. It has been found, for instance, that unnecessary or unwise drainage of our swamps is sometimes the chief cause for the depletion

of a once-abundant fish fauna in an adjacent stream or lake. Such a body of water can be continually restocked at great expense, or the swamps may be restored to their pristine condition and the fish restored by their own procreative ability.

It is with this idea in mind that the State of Louisiana has of late been proposing a departure from the beaten path and recommending expenditures of money in order to benefit the natural conditions or restore nature's fish hatcheries, instead of increasing the number of her artificial hatcheries.

As an example of what we mean, there has been a popular demand for a fish hatchery for buffalofish in the neighborhood of Jonesville, Louisiana, and as a result of this demand the Legislature appropriated $15,000 for the building of such a hatchery. After a study of the conditions in the waters around Jonesville, it was found that there was an ample supply of both game and commercial fish subsequent to every flood year. On the other hand, fish would become very scarce after every drouth. During such drouth periods, Catahoula lake and other lakes, rivers, streams and bayous in this vicinity became either dry or very shallow, and the fish which were crowded therein had little opportunity to spawn or the young produced could not compete with their own parents or with the predaceous fish found in these waters. The young of both game and commercial fish thrive best in flooded swamp lands, where their food is abundant, and when deprived of these areas, there is a short crop of fish. It would seem, therefore, very futile to hatch fish in a fish hatchery during the years when the waters could not support them, and it is unnecessary during flood years, when there is an ample supply of fish food and an overproduction of fish.

We have found that at approximately the same cost of building a purely artificial hatchery at Jonesville, that the State of Louisiana could dam the outlet of Catahoula lake and thus create a natural fish spawning ground of some 100 square miles in area in place of a purely artificial hatchery as used in the early days of fish culture. We are therefore recommending that the State place a dam in the outlet of Catahoula Lake in order to hold the water at all times in swamps which are flooded for a period of ten months, during a favorable year, anyhow. With this and a number of other similar projects which we are contemplating, we believe we can build up our fisheries at a minimum cost in proportion to the results to be expected and at only an infinite fraction of the cost of operating artificial hatcheries and culture stations when figured in terms of the increased number of fish caught by the anglers and commercial fishermen.

Louisiana, being blessed with an abundance of fishing streams and lakes, and a great expanse of swamps and backwater areas which serve as natural hatcheries and refuges for young fish of the species found in her streams and lakes, is in an excellent position to increase her fisheries manifold by taking advantage of nature's own favorable conditions and assisting them during adverse periods. Thus, with the dawn of a new day in fish culture, our State finds itself a pioneer and leader in the practical application of many new ideas, which find their conception in a scientific study of the fish and their natural environments, and which are designed to improve the quantity and quality of the fish supply by modification of the environment when possible, rather than by supplemental fish culture.

Discussion

Mr. Vogele: What is the approximate fluctuation in the temperature of the water?

Mr. Viosca: The surface temperature generally runs between 80 and 100 in the summer.

Mr. Vogele: Perhaps that would account for the remarkable increase.

Mr. Viosca: I think temperature is of considerable importance among several other factors, such as the length and character of the shore line and the tremendous amount of food. We find, for instance, when we plant sunfish and bass together we get a much larger production of bass than if we planted no sunfish. Sunfish are not cannibalistic; they multiply rapidly and they serve as food for the bass. Our usual production is about 10,000 black bass per acre in ponds in which the fish are not fed.

Mr. Vogele: What is the area of the pond?

Mr. Viosca: Twelve acres.

Dr. A. H. Wiebe (Iowa): I would like to ask Mr. Viosca how he knows that there is no cannibalism? If I remember correctly, he said that the fry pass into the next body of water without being handled, which means, without being counted. It would be difficult to know whether or not some of the fry had disappeared.

Mr. Viosca: Our idea was to utilize cannibalism as a source of food, if necessary. But there seemed to be little evidence of cannibalism as far as we could tell, although we did not examine any stomachs. There were a large number of bass swimming around in schools, and at night when the small crustacae would accumulate under the electric lights the black bass would feed. If there were marked cannibalism among the bass, therefore, we would have discovered it. There must have been some cannibalism, because there was considerable difference between the maximum and minimum-sized bass.

Dr. Wiebe: We have very little evidence of cannibalism in our ponds, yet

if we have fifty per cent survival of the fry by actual count it is exceptional. It seems to me that cannibalism has something to do with it. It would appear to be extremely desirable that wherever possible we get away from estimates. In experimental fish culture it would seem desirable to obtain actual counts. Before we publish papers, we should at least know as nearly as possible the size and age of the fish, and what per cent of bluegill, bass or other species we are handling.

Mr. J. Wicks (Minnesota): As I understand Mr. Viosca, the fish are released through this outlet in Lake St. John?

Mr. Viosca: Yes.

Mr. Wicks: I am wondering whether there are any objections to that method of releasing them. Do you find that the enemies of these young fish gather at the inlet? Would it not be better to distribute them at different points in the lake?

Mr. Viosca: Under the conditions we could not do anything else but release the fish. We did not notice any fish enemies. With proper equipment we expect to distribute them throughout the entire lake.

In connection with what Dr. Wiebe has said, we know the ratio of the different species, for instance of sunfish to black bass. We have the percentages and they are not simply guesses. We actually made seine hauls over given areas and took the weight of the fish. We took size groups and classified them. We hardly believe these figures ourselves and we do not expect you to believe them, but they are facts.

Mr. G. Amsler (Arkansas): Where do you contemplate getting the water from during the dry years in those lakes?

Mr. Viosca: We have quite a number of lakes that are spring fed. Catahoula Lake, which consists of about one hundred square miles, goes dry only once in perhaps three or four years, and when it does the spring-fed streams run right down the center. It is on the edge of the back-water area, and when the water of the Mississippi River, Red River, or the Black River is up, the back-water goes into that area, so that the spring flow would keep up the water level. The whole spring-fed watershed of north and central Louisiana comes down through that lake.

Mr. E. L. LeCompte (Maryland): I have listened with a great deal of interest to Mr. Viosca's paper, and I think he should be congratulated on bringing to the attention of the fish culturists this system of fish ponds. There is one feature I have not heard commented on, one which I regard as essential in all fish ponds, and that is the wiring of the spawning beds so that the fry can be separated from the spawning fish. You can not leave the fish fry, especially bass, in the pond with the brood stock. Fencing a certain portion with one-inch poultry mesh would enable the small fish to get away from the areas in which the brood fish were confined.

The majority of the States have a policy of taking the fry out of the brood ponds and putting them into holding ponds. This scheme would eliminate that necessity and would require a smaller water area for the propagation of black bass than the system used by the majority of the States at the present time.

MR. G. C. LEACH (Washington, D. C.): The average fish culturist may be skeptical with regard to Mr. Viosca's figures. It is usually hard for those who have not had experience in bass culture in the southern States to understand how bass and other warm water species can be raised on such a large scale. If Mr. Viosca's plan were tried out in Montana or northern Dakota or New York it might not work so well, on account of food scarcity. His plan worked successfully because all our southern States, especially Florida and Louisiana, are natural fish hatcheries. About all you need is fish and protection and a few adding machines, and the result is a successful job. The production of warm water fishes in Louisiana requires only a little scientific study and careful investigation in regard to the habits of the fish. Not more than about ten fish to the square foot of water can be maintained without overcrowding. In fish culture you have to consider the point at which there may be overcrowding so far as the food supply is concerned.

In shipping the fish out to applicants in cans where you have to count your fish, our results are never so impressive as the figures with respect to fish that are turned loose in streams. Always a certain degree of personal enthusiasm enters into the estimate.

If you put a screen around the pond and expect the young bass to keep out of the screened area and go out into the wide open spaces, you will find that they will go into the screened areas where they ought not to be. But the older fish seldom bother the younger fish. The spawning extends from the 1st until the 20th of May. The first brood will as a rule prey upon the successive broods, so that in the end you have the original brood and possibly a few lucky survivors of succeeding broods. The screening of ponds has never been successfully carried out because it is the young fish that prey upon each other.

In Oklahoma, where we have tried a new scheme in the rearing of fish, our brood ponds will be half or three-quarters of an acre in area. The brood pond will be stocked with a limited number of adult fish. We expect to transfer the young fish to nursery ponds as soon as they are hatched. In the brood pond are fifteen females, each capable of producing five thousand fish. We aim to transfer five thousand fish to each of our brood ponds, in connection with which are daphnia ponds and minnow ponds. Each group will be a unit, possibly in a forty-acre field or section.

In southern Georgia we expect to turn our bass, bream, and crappie loose in the spring in a pond of 225 acres and let them shift for themselves until October; then draw down the pond and take chances on the crop, somewhat similar to the practice on the western ranches where they run their sheep and cattle all summer long and then put them on the market in the fall.

MR. W. TUCKER (Texas): One thing of importance that Mr. Viosca brought out is the abundance of shallow area and shore line. All of us who

have had experience in propagating black bass know that shore line is important. Mr. Viosca was thoughtful enough to make his levies run north and south so that he would get an equal division of sunlight. As an outsider, I am prepared to believe his statement regarding these fish. Some of you gentlemen from the north may be interested to know that the spawning season in Louisiana and Texas, with which I am familiar, started this year on the first of April and continued well past June. Indeed, we had fish spawning the first of July. By actual count, with our fingers, and no adding machines, we took out 3,600 bass fry and placed them in a half-acre pond in order to conduct a feeding experiment. The bass were hatched out on the 10th of April and removed from the pond the day they rose from the nest. On the 16th of August, a little over four months, we drained the ponds, and out of the 3,600 put in we got 80 large-mouthed black bass ten inches in length and 230 that were two and one-half to three inches in length. There was no doubt that there was cannibalism in that pond.

I am going to conclude by asking Mr. Viosca a question that I regard as important. How much fish refuse did you place in your pond?

MR. VIOSCA: I have not the actual figures with me, but it would be from 100 to 500 pounds a week. When we could not get refuse from the gillnet fishermen, we seined large numbers of gizzard shad.

THE ARTIFICIAL PROPAGATION OF FRESHWATER MUSSELS

By M. M. Ellis

Professor of Physiology, University of Missouri and Special Investigator U. S. Bureau of Fisheries

In presenting a discussion of the artificial propagation of freshwater mussels to this Society the question which naturally arises is that of the relation of mussels to fisheries' problems. The contact comes through the peculiar life cycle of these bivalves.

During the course of their studies several of the early zoologists noted that occasionally large numbers of tiny animals were to be found packed in the gills of certain European freshwater mussels. Unfortunately the fact that these almost microscopic forms occurred only in the gills of the female mussels, was not properly correlated and as it was supposed by some scientists that these little animals living in the gills were parasites, the name *Glochidium parasiticum* was given to them. In 1866, however, a German zoologist, F. Leydig, demonstrated that the glochidia live as parasites on the gills of fishes. From this work of Leydig and that of Braun in 1878 it was definitely established that the glochidia are gill parasites of fishes and as such are merely passing through a stage in the life cycle of freshwater mussels, instead of being parasites on these same mussels as some of the earlier observers had reported.

Just how serious glochidial infection under natural conditions is to the fish is still a matter of discussion, although it is known that by experimental means at least a fish may be overloaded with these gill parasites and injury or death from fungus diseases or other causes may result; but aside from the possible injury to the fish host, the parasitic habit of the glochidia of these freshwater mussels has an even more important bearing on fisheries' problems through the selection of particular species of fish by these glochidia as their sole natural hosts.

The first application of these scientific observations to American mussel and fisheries investigations was made nearly twenty-five years ago. In the early nineties a German, John Boepple, began the manufacture of buttons using freshwater shells collected from the Mississippi River and tributaries. Boepple had had experience in the manufacture of buttons in Germany and although he did not come to this country for the specific purpose of making buttons he was early impressed with the superior quality of the American freshwater shells. Consequently he set up a foot-power machine in a small building in

Muscatine, Iowa, cutting and finishing his buttons by hand. Capital was soon interested in Boepple's project; inventors turned their attention to the problems of button machinery, producing shortly the automatic button machine; and factories were established for the cutting and finishing of buttons, with the result that the mussel beds of the United States in the course of a few years became important commercial assets. Enormous numbers of shells were collected and only the choicer varieties saved, with an attendent waste similar to that suffered by many other natural resources during the first period of exploitation. This almost unrestricted digging of mussels without any restocking of the waters other than that taking place by natural means would in itself soon have made serious inroads in the mussel fauna of many streams, but the discovery of freshwater pearls added the rapid and unnecessary destruction of many more shells.

It is a well known fact that the fresh water mussel produces a deposit of pearly nacre around any foreign object deposited in its mantle cavity, and it was not surprising that with the rapid opening up of American freshwater mussel beds and the consequent gathering and handling of large numbers of these mollusks that valuable pearls should be found. The quality of the freshwater pearls was excellent and amazing prices were paid for them. Consequently large numbers of diggers began the wholesale collection of all sorts of fresh water shells which were opened and thrown aside after they were examined for pearls. Many of these piles of discarded shells now weathered and useless, can still be seen on the banks of various mussel producing streams. So as a result of an increasing demand for shells by the button industry, and the ruthless destruction of large numbers of shells by the pearl hunters, the manufacturers soon found their natural supply of shells dwindling.

During the years 1905-1911 Professors Lefevre and Curtis of the University of Missouri made an extended series of investigations for the U. S. Bureau of Fisheries on the life histories and biology of the North American freshwater mussels. It was through the work of these two men, who applied the discovery of Leydig to American species and then greatly amplified it with their own researches, that the first plan for artificial propagation of mussels was perfected. Their studies showed that the long-nosed and short-nosed gars are the host fish for our most valuable fresh water shell, the yellow sand-shell (*Lampsilis anodontoides*), and that the host fish for several of the valuable muckets are the bass, the sunfish and the crappie. With the host fishes of the yellow sand-shell and Lake Pepin mucket definitely determined, the U. S. Bureau of Fisheries began the artificial infection of the proper host fish with glochidia of these two species of mussels, releasing the infected fish in natural waters.

The plan followed by the Bureau of Fisheries consisted essentially in infecting fishes recovered by the rescue crews from sloughs and backwaters in late summer, with glochidia before these fishes were returned to the river. No gars were raised for the purpose, and only fishes which would have perished otherwise, were used as hosts for the glochidia.

Again, however, we have an important contact with the fisheries' problem. The merits and demerits of the gar are only too well known to most fisheries men, and the high esteem in which the bass is held as a game fish needs no comment. The problem is evident. It is absolutely essential to the life of the yellow sand-shell under conditions obtaining in nature that it spend a parasitic period from eight to thirty days, or even longer, on the gills of the gar. No other fish will answer, as there is no substitute in nature for this host. The conservation of the yellow sand-shell under natural conditions therefore involves at once the conservation of the notorious gar,—which is not entirely desirable, at least from the standpoint of the angler and sportsman.

It is well perhaps at this point to outline the life history of the yellow sand-shell as typical of the American species. Enormous numbers of eggs, often in the millions, are produced by the female sand-shell and after fertilization these are forced into special portions of the maternal gills. There they undergo a partial development transforming into a stage known as the glochidium. At this stage the embryonic clam consists of little more than a pair of tiny shells held together near their hinge by a relatively large muscle. Back of this muscle and forming a very thin lining for these shells are small masses of delicate embryonic cells from which under proper conditions, the various internal organs of the mussel are developed. These glochidia which are so small that a single individual is barely visible to the naked eye, remain in the maternal marsupium, as this portion of the gill is called, for several weeks. When glochidia are properly developed they can be extruded by the female mussel through the siphon into the surrounding water. The extruded glochidia with their shells gapping widely, float out and if by chance they come in contact with the gills or fins of passing fishes they snap shut, closing themselves on the tissue of the fish. Biochemical tests demonstrate that the glochidia when extruded from the female clam are extremely sensitive to certain types of stimuli which are, of course, factors in the closing of these embryonic animals on the tissues of the host. From experimental observations of Professor Arey of Northwestern University, it is known that the glochidia are quickly encysted by the tissues of the host fish so that a glochidium finds itself completely covered with a cyst produced by the fish in the course of 3 to 6 hours after attachment to the

gill. If the glochidia from the yellow sand-shell have been fortunate enough to locate themselves on the gills of the gar, after they are encysted their development may continue. If, however, they have attached themselves to fishes other than the gar, even though they become encysted, after a few days they are sloughed off by the unsuitable host fish and are lost. It is obvious then that the enormous number of eggs produced by a single female constitutes an adaptation to insure at least a few of the glochidia maturing in a life cycle so dependent upon what one might term successful accidents. After a glochidium is encysted on the gills of the gar this embryonic yellow sand-shell begins a definite internal growth. There is very little change in size and practically no change in external shape during this parasitic stage, but from the embryonic cells internal organs and a muscular foot well covered with ciliated cells are developed. When these internal changes have proceeded to the proper stage, usually a matter of 14 days or more, the cyst is ruptured and the glochidium drops from the fish onto the bottom of the stream. Some bottoms are favorable, others distinctly unfavorable to development of this tiny animal which is now about to begin its independent life, and again, it is evident that the chances are many that the juvenile mussel, as it is now called, will not reach maturity. Granting that it is fortunate enough to fall upon a suitable bottom the juvenile begins its active life, and, barring encounters with enemies, failure of food supplies and changes of environment, in three to five years the shell is large enough to be of commercial value to the button manufacturer.

The plan of artificial infection of suitable host fish with proper glochidia therefore reduced the chance of loss in the first stage away from the maternal mussel. It also greatly increased the number of glochidia carried by the host fish, as in nature the number of encysted glochidia per fish is quite small, while by artificial infection each fish could be made to carry several hundred to several thousand glochidia.

A growing foreign market for certain American freshwater shells and a steadily increasing domestic demand for shells by our manufacturers, together with changes in the environment brought about by stream pollution from the large cities along the rivers and by channel changes made necessary by navigation demands, have continued, however, to reduce the supply of available mussels in the principle streams of the Mississippi drainage in spite of the artificial infection of natural host fishes.

In 1925 the writer began a series of experiments looking to the elimination of the parasitic stage on the fish by the substitution of a suitable fluid in which the glochidia could be caused to develop under controlled conditions in the laboratory. It is obvious that if the glochidia could be carried from the time they leave the maternal marsupium until they

transform into juveniles in some sort of hatching unit, the juvenile mussels could then be planted on suitable bottoms in streams known to be favorable to the development of mussels and the critical events of proper encystment on suitable hosts and of landing on favorable bottoms entirely eliminated. The distribution of the juveniles hatched could also be regulated as they could be planted directly in the localities desired.

In developing a method for this type of propagation the causes of the parasitic stage on the fish gill and the value of this stage to the mussel were first investigated.

Many species of animals are parasitic during some stage of their life history to insure transportation into favorable or uncrowded fields. The first tests in glochidia studies were directed against the problem of transportation. It is clear that these almost microscopic embryos when discharged into a moving river stream would be swept down stream and ultimately moved out into salt water unless some provision for their attachment was made, and even so they would probably fall or attach themselves some distance down stream from the place where they were discharged. This would favor a progressive down-stream migration of the species, which would tend to move it into salt water. A short period of attachment to a fish, however, would provide transportation up-stream as well as down-stream, and it seemed possible that this transportation was all the parasitic sojourn on the fish provided the mussel, especially since it is known that the glochidia of most species increase very little in size while in the cysts on the fish gill.

As the environment in which the glochidium finds itself after encystment on the fish gill had to be duplicated the components of the host fish blood were determined and tried singly and in various combinations, as the encysted glochidium is bathed in the fluid part of the fish's blood.

In the first tests a mixture of salts equivalent to the salts found in the host fish blood was made and when properly aerated it was found that the glochidia taken from the female clam would live in this solution for many days, but with little or no development. Finally in every case death resulted. The failure of the glochidia to develop in salt solutions, which of course have no nutrient value as far as growth is concerned when administered without other substances, showed that the glochidium is dependent upon the fish for something more than merely a suitable environment for transportation.

As fish blood contains a considerable quantity of blood sugar, an energy food, in the next series of tests sugar of the proper sort and in proper quantities was added to the salt mixtures. The glochidia lived for longer periods in solutions of the mixture than in the salt solu-

tions alone, but as it is a well established physiological fact that growth and repair of tissue cannot take place on diet of sugar alone it was not surprising to find that the glochidia finally died in the sugar-salt mixtures. The nutrient solution, for such it must be called as repeated tests demonstrated conclusively that the glochidia do obtain food from their host, was next augmented with various protein derivatives. Finally, after many tests a mixture of salts, sugars and protein derivatives was found in which the glochidium would complete its development of a ciliated foot and other internal structures just as if it were encysted on the gill of a suitable host fish. In these experiments the glochidia were handled singly or in groups of two or three, but once a suitable nutrient fluid was found the researches were directed toward methods of handling the glochidia in numbers large enough to make process of value in restocking streams and other waters.

The problem of handling large numbers of glochidia has not been without its difficulties. Bacteria, protozoan, parasites and molds of various sorts can utilize the nutrient solution quite as well as the glochidia themselves, so that measures for the proper sterilization of the cultures had to be taken, as these studies of large numbers of glochidia have progressed it has been learned that although a single female mussel may produce millions of glochidia, not all of these are viable, and many which are capable of attachment and encystment never complete their development. Many glochidia are killed in the marsupium before they are discharged in the water, and still others are enfeebled by attacks of protozoans and bacteria to such an extent as to be worthless for propagation work.

These findings have necessitated a search for vigorous breeding stock and it may be noted here that the decline in the viability of the glochidia from mussels taken in the upper Mississippi River has been very evident by a comparison of these glochidia for the past four summers. During the season just now closed it has been practically impossible to get healthy, vigorous glochidia from Lake Pepin and from several other Stations along the Mississippi where gravid females have been collected in the past for propagation purposes.

The new method of propagation which eliminates entirely the parasitic stage on the fish opens many new possibilities in connection with mussel culture. It is now possible to select breeding stock with reference to quality and character of the shells, and the button manufacturers know only too well that many seemingly good shells are either too brittle or too soft when put into the hands of the cutter; species of mussels, the host fishes of which could not be readily obtained, may now be considered; and perhaps best of all, the stocking of favorable localities with juvenile mussels will assure the manufacturer of a crop of shells so that he will not have to depend upon the accidental transportation as accomplished by the host fish.

XXVI.—Discussion

MR. C. AVERY: I would like to ask Dr. Ellis whether or not the practice that was introduced a number of years ago of closing selected areas to clam fishing for a period of years has been beneficial.

DR. ELLIS: In some places it has been distinctly beneficial. In certain closed areas, however, because of local conditions the clams have not prospered. In one instance the influx of pollution killed or prevented the maturing of the glochidia, which developed brown spots in the shells.

MR. AVERY: Is this method of protection still followed in the waters of Minnesota, Wisconsin, Illinois and Iowa?

DR. ELLIS: It is followed in some localities, but in others it has been discontinued.

MR. G. W. MCCULLOUGH (Minnesota): Has there been some improvement in Lake Pepin, where the area has been closed since 1922 until the present year?

DR. ELLIS: The Lake Pepin fishery is among the poorest as far as replacement value is concerned. We have been unable to get any glochidia there for the past two years, and the breeding stock is practically worthless. I do not know about the increase in the size of the shells, but the present quality is not good.

MR. MCCULLOUGH: You would attribute the failure of quality to the fact that the Mississippi is heavily polluted?

DR. ELLIS: Pollution may affect the developing embryos in the parent; and yet may be of such a nature as not to kill the clam. Field and laboratory experiments have demonstrated that the developing embryos can be killed without serious injury to the adult clam.

PRESIDENT CULLER: The button manufacturers recently have furnished data which show that by artificial propagation and by closed season the Pepin mucket has increased in Lake Pepin from twenty-seven to sixty-two per cent.

FISH CULTURE IN MINNESOTA, PAST, PRESENT AND FUTURE

By Thaddeus Surber

Supt. Fish Propagation

Minnesota Game and Fish Department

From the view-point of the fish culturist the importance of any state is based primarily upon its water area. This point was recognized at the inception of the Minnesota Fish Commission in 1874, when the desirability of aquatic farming was brought to the attention of the Legislature and the many advantages that might accrue to Minnesota on account of its immense area of water surface particularly stressed. At that time its real capacity was not fully recognized, yet the second annual report of the State Fish Commissioners in 1875 gave some estimates on the possibilities of the future by showing that if each acre of water surface in the lakes of the state were, at that time, made to yield but two pounds of fish per acre, at an average price of 5c per pound, the quantity produced would have a valuation of $16,018,400.00 annually. In those days, however, vast areas of the state were unknown. Consequently the acreage of the lakes which were then held to be approximately 1,601,840 acres, can, in the light of our present knowledge, be safely doubled in spite of the fact that over 500 lakes have, through unwise drainage or other causes, become dry.

The Commissioner of Drainage and Waters in a recent publication (Gazetteer of Meandered Lakes of Minnesota, July, 1928) gives the total area comprised within the 6,489 listed lakes as 2,368,493 acres or 3,701 square miles. These figures, of course, comprise only those bodies of water that have actually been meandered and he very aptly calls attention to the fact that the unmeandered lakes of our state may well outnumber the meandered ones, yet the additional area is comparatively small.

There is, at the present time, no information as to the number of miles traversed by even the larger and more important streams of the state, let alone the thousands of small tributaries which augment their flow, and therefore, it would be unsafe to even venture a guess at the thousands of miles of streams available or adaptable for fish cultural purposes. For an illustration of the magnitude of these streams attention is called to the fact that the Mississippi River alone flows a distance of 660 miles from its source in Lake Itasca before it leaves the extreme southeastern corner of Minnesota.

At the time the State Fish Commission was founded in 1874, seventeen other states had taken up this enterprise, but all of them, with the exception of New York, were operating on scanty appropriations so that it is not surprising to learn that the first appropriation for the

operation of hatcheries in Minnesota consisted of but $500.00 for the year 1874. With this scanty appropriation little could be done and what few eggs were handled and fry planted during the three ensuing years, were handled in two private hatcheries, one located on the St. Croix near Stillwater and the other near Red Wing.

It is extremely interesting to the modern fish-culturist to learn the product of these hatcheries. For the first few years particular attention was directed toward introducing the Pacific and Atlantic salmon, the land-locked salmon of Maine and even the shad of the Atlantic Coast. It is quite evident that the condition of the lakes and streams in Southern Minnesota in the late 70's and early 80's was highly favorable to fish life because the report of the State Fish Commissioners for 1878 indicates that some of these California or Pacific salmon planted in certain lakes in Rice and Dakota Counties had acquired a weight of 2½ lbs. and had reached a length exceeding 16 in. It is interesting in these old reports to find records of the planting of thousands of salmon and the Lake Superior whitefish, not only into the lakes of the southern half of the state but in such rivers as the Minnesota, the upper Mississippi, and the Root River. This planting occurred years before the craze for drainage had reached the state and no doubt many of these streams, because of the quality and volume of water, were at that time as justly adapted to the introduction of these species as many of the streams on the Atlantic or Pacific Coast.

About 1880 or 1881 the carp craze penetrated the state and the report for the years 1881 and 1882 devotes a good deal of space to a history of the attempt made to obtain a supply through Professor Baird, U. S. Commissioner of Fisheries. In January 1882 the Superintendent of the St. Paul Hatchery made a special trip to Washington to secure, in the words of the commission, "Some of the much coveted German Carp, promised us by Prof. Baird sometime ago. He returned the last of the month, bringing with him 69, large enough for breeders and 109 small ones; he was fortunate enough to lose but 3 of the small ones on his journey home." The majority of these carp were turned into a large pond built for the purpose, "We also placed 8 of them in a small and suitable natural pond, whose locality and name we think as a safe precaution better not designate lest the carp be stolen." Along in March of the same year our old friend Frank N. Clark of Michigan, on order of Prof. Baird, shipped 600 carp fry to the Minnesota Commission.

Little did these commissioners realize at that time that many thousands of dollars would be spent in a frantic effort to eradicate carp from the southern lakes some 50 years later, but they were right in one thing, the lowly carp has produced since its introduction in Minnesota more real revenue to the state than any other aquatic animal. The question naturally arises, was it the part of wisdom or was it not to introduce these fish? Misguided sportsmen have blamed the carp for the present

condition of lakes and streams in the southern part of the state! This idea is wrong to a great extent because the most damaging factor in the elimination of lake fishing in the southern half of the state lies in that policy of drainage, which lowered the water table 10 ft. or more and every lake, stream and spring along with it through a vast area of beautiful lake country, at a cost of upward of $400,000,000 to the people of the state.

In the light of our present knowledge it would seem ridiculous to attempt to stock our waters with the Quinnat salmon, the Atlantic salmon, or the land-locked salmon, because every condition existing in our waters is against success, but we should not criticise the early commissioners, or the fish culturists whom they employed, for attempts to introduce these desirable species because we can hardly realize at this time the exact conditions existing in those days when there was no drainage, no destruction of our forests and peat bogs by fire, and no cultivation of areas around the headwaters of our streams, all of which necessarily follow an increasing population.

Modern fish culture in Minnesota dates from the year 1914. It is true considerable success had been attained in maintaining pike fisheries in our lakes, but up to that time, and for a few years thereafter, the steady decline in stream fishing persisted owing to reduced water flow, increased temperature from the destruction of the forest and cold swamp feeders on headwaters and other natural causes, followed by futile attempts to maintain trout fishing in streams by the introduction of millions of fry at the improper season.

The importance of a biological reconnoissance of the lakes and streams of this state was recognized by Commissioner Carlos Avery. The surveys which were started in 1917 enabled the Department to formulate a really scientific plan for future development, but the development of these plans called for far more funds than were then available through the appropriations made by the legislature.

Even as late as 1920 politics still played an important part in the selection of hatchery sites and the distribution of the output. All of the hatcheries in operation had been selected to please politicians without any regard whatever having been paid to the suitability of water supply or the location of the hatchery with a view to an economic distribution of the output. Consequently a sane and equitable distribution of the output of these hatcheries was sadly handicapped.

Mr. Avery was the first commissioner to recognize the futility of attempting to propagate the nest-building fishes in the small areas provided by the ponds at the three hatcheries. However it was not until toward the close of his administration that the idea of setting aside and protecting during the spawning season certain natural spawning grounds in our lakes, one of the greatest advances in fish conservation ever made in this state, was put into effect.

Through faulty construction of ponds, long continued use and a

diminishing water supply at two of the older hatcheries—St. Paul and Glenwood, fish diseases had gained such a foothold that it became necessary in 1923 and 1924 to destroy all of the brood stock, consisting of thousands of adult brook and brown trout, and seal the ponds with cement construction.

In 1923 the legislature became convinced of the futility of attempting to relieve immense drain upon our trout streams by the introduction of fry, and increased appropriations so as to permit fry to be reared to fingerling size. In a year's time the results were so convincing that during the 1925 session no difficulty was experienced in further increasing the appropriations.

Of greater importance still, during this session, was the passage of a bill appropriating money and authorizing the construction of a new trout hatchery in the southeastern part of the state, selected solely upon the merits of the water supply and without any consideration of political influence. The completion of this hatchery during the fall of 1928 has demonstrated the wisdom of this selection because the water supply is of such volume and character as to permit the rearing of all trout to from three to six inches in size before planting, thus avoiding planting at that season of the year when food is scarce and the spring floods do most damage.

At the older hatcheries, St. Paul, St. Peter and Glenwood, trout are reared to the fingerling size, but they never attain the same size during an equal period that trout attain at this new location. The gradual disappearance of the water supply at these older hatcheries has curtailed their output fully 50 per cent during the past twelve or fifteen years and now is a menace to their future.

The planting of fingerling fish during the past five years has clearly demonstrated that many waters which we deemed unsuitable can be made excellent trout streams so that we are now enabled to attract anglers over an area of the state fully double the area utilized ten years ago.

Attention has been called to the inauguration of a policy of setting aside natural spawning grounds for bass, crappie and sunfish in our lakes as the most feasible means of perpetuating these important fishes. This is an extremely important matter but under the existing laws can be pursued only to a certain extent. I believe it is a well established rule with modern fish culturists that it is impossible to construct a pond with too great an area for the cultivation of black bass provided it is so constructed as to permit of absolute drainage and control. This has been demonstrated very forcibly in a pond acquired by the Minneapolis Izaak Walton League three years ago, the operation of which has been carried on by the Minnesota Game and Fish Department during the past two years. This 20 acre pond is not as yet in condition to furnish its optimum productivity and in all probability will not be in such condition as to permit of intensive fish cultural operations for two or three years hence, yet the output of this pond during the 1928 season

was 68,000 fingerling bass, from four to six inches in length, and in addition about 700, seven to ten inch bass.

The propagation of wall-eyed pike, which is both a commercial and game fish; and the whitefish which is purely a commercial species, is extensively carried on in Minnesota. That it is highly successful has been demonstrated in hundreds of cases, particularly by the introduction of pike into waters in which they were previously unknown. In some instances excellent fishing has been produced within a period of three years after the introduction of pike fry.

There has been a great deal of agitation demanding that we rear pike to fingerling size before planting. As most practical fish culturists know this idea is preposterous on account of the well-known cannibalistic propensities of this fish. We have clearly demonstrated that where pike fry have been carried to deep waters and planted there is no question as to the success of such plants, but on the other hand where planted under the old system of dumping them in comparatively still water along shore, they simply serve as a meal for shiners and are, therefore, nearly a complete loss.

The demands of the future must be met, but we must first have certain facts before plans for any considerable expansion is made. The agricultural and dairying industries in this state are steadily increasing, demanding more and more cleared areas in the upper half of the state. Forest fires are annually claiming thousands of acres of forest land. These necessary industries, coupled with the havoc wrought by forest fires, produce the same effect that unwise drainage did in the southern and western parts of the state, so that eventually lakes which are now pretty much as nature fixed them, and streams which now flow an abundance of cold water, will be so reduced in area and the temperature so much increased by deforestation that the posibility of maintaining great numbers of fish in their waters will be hopeless. Certain lakes in the southern part of the state will necessarily have to be abandoned to the carp because we must recognize the importance of the carp in this commercial age and its importance is but enhanced by the incapacity of the waters of many of the southern lakes under present conditions to care for the native species.

It will be possible to introduce crappies in practically every lake in the northern part of the state because experience has demonstrated that they thrive in all of the northern waters. This, however, is not true of the bass because they spawn earlier in the season and the severe climatic conditions and sudden changes of temperatures in the northern tier of counties renders their successful introduction doubtful, or at least the rate at which they respond to introduction is extremely slow. It has been clearly demonstrated at our Detroit Hatchery that we can expect a bass crop but one year out of three because of sudden temperature changes due to climatic conditions. We must, therefore, secure legisation making it compulsory to set aside certain areas to protect the basses

and other nest-building fishes in all lakes inhabited by them and see to it that such orders are implicitly obeyed.

Experiments now being conducted indicate that it will be possible to successfully rear lake trout in suitable spring water, but of course we do not yet know whether they will mature so as to permit us to take eggs from brood stock in the same manner as stream trout. There is no question in my mind that lake trout should be reared to fingerling size before planting and I hope to see the day when this will become the universal practice in those states which are fortunate enough to have lake trout waters.

One of the problems confronting us at this time is the question of the natural food supply for our lake fishes. It has not yet become serious in our streams because most of the streams from which minnows were obtained and marketed are automatically closed when they are stocked with trout, especially since we have recently overcome some of the adverse conditions in the warmer streams of the state, by the introduction of a Missouri strain of rainbow trout. Unless the wholesale gathering and marketing of bait minnows can be stopped the game fish capacity of our lakes is going to be reduced one-half, since the maintenance of fish life in any public water depends upon the available food supply. Certain investigations have been carried on for the last four or five years looking to the artificial propagation of various species of minnows, but the outlook is not at all hopeful for immediate success.

Unlike several other states, Minnesota has been unable to collect from its trout streams any eggs of wild trout for replenishing the stock maintained at the various hatcheries. The inland lakes inhabited by lake trout invariably freeze just at the time when the lake trout begin to spawn and by the time the ice is of sufficient thickness to permit operations, the spawning season is closed. Therefore we have to rely upon the waters of Lake Superior for our entire crop of lake trout eggs, but through cooperation of commercial fishermen, our annual harvest is keeping pace with the increasing introduction of lake trout fingerlings.

Five years ago we were purchasing outside of the state about eight million brook and brown trout eggs annually. As previously stated it became necessary to destroy all of the old brood stock of these two species because of the prevalence of disease. Since that time we have built up a new brood stock of brook and brown trout, have undertaken the propagation of rainbow trout on a larger scale and at this time produce such a quantity of eggs from our station brood stock that we are no longer forced to purchase one-third of the number bought in previous years. With ordinary precaution and proper feeding of the brood stock it is believed that another year will see the end of egg purchases outside of the state. Selective breeding is producing such results that our hatcheries will be able to produce a sufficient quantity of eggs to meet all demands.

There has been a great deal of agitation during the past two years for fishways in the many dams already installed or being installed in the rivers of this state. I believe it is a well-known fact that fishways are utilized only by migratory fishes; to the greatest extent by such fish as the salmon and trout. We have determined that about the only fishes in Minnesota which utilize even the most practical fishway, and we have several types in common use, is the sucker and the carp. So far as my personal observation goes, pike never take advantage of these fishways. Trout remain throughout the year in streams actually adapted to their habitat, consequently, the only fish that we have ever found using them are such fish as we would prefer to have remain in the larger streams.

As stated before the importance of the carp is fully recognized, but in our efforts to hold this fish in the waters which he now infests we have had to adopt a policy of closing such fishways as had been installed in previous years and decline to order the construction of any additional fishways in such dams as would prove an effective barrier to the further encroachments of carp upon the lakes tributary to the Upper Mississippi and its tributaries. This has not been accomplished without severe criticism not only from laymen but more surprising still, from sportsmens' organizations. The greatest damage done to Minnesota waters by the carp is accomplished through the active competition of millions of young carp for the identical food which rightfully belong to our young native game fishes, and not, as many suppose, to the destructive habits of the adult carp themselves.

The expenses of operating state hatcheries and distributing their output, has grown from the pitiful sum of $500 in 1874 to approximately $100,000 in 1928, with a corresponding increase in the output of young fishes from 51,000 in 1875 to approximately one billion in 1928-29.

In addition to the ever increasing army of resident sportsmen and anglers we have widely advertised to the anglers in the United States the many advantages possessed by Minnesota in his favorite recreation, with the natural result that many thousands of anglers outside the state take advantage, and add to the increasing drain upon this resource.

Our hatcheries would now be able to produce an ample supply of pike fry for maintaining lake fishing for years to come were it not for one fact. The most vicious law on the statute books of Minnesota today is the one which legalizes the netting of whitefish for private use. Each member of a family is entitled, upon payment of a fee of $1.00, to own and operate 100 ft. of gill net. The season extends from November 1 to December 10. There is no limit to the number which can be so taken. Unfortunately some of our best pike lakes are also the abode of whitefish and we have numerous instances of the practical depletion of the pike through the use of these nets, as the legal mesh used is just the right size to catch all matured pike, leaving only the one and two year old pike to

survive. Unless this law is repealed the doom of the pike is assured in many lakes in spite of artificial propagation.

Our ability to produce an ample supply is also true so far as it applies to the maintenance of our trout streams if we exclude those tributary to the North Shore of Lake Superior. These North Shore streams are fished so persistently, and forest fires have wrought such havoc with many of the streams in not only reducing flow but in causing a tremendous increase in temperature, that considerable stretches of certain streams are no longer suitable for trout during the warm season of the year. Many of these streams, as well as a few streams in other sections of the state should be closed for three years to all fishing in order to permit their restoration to a measure of their former capacity. This can be accomplished if we can obtain the whole-hearted support of the anglers most deeply interested. It will cause absolutely no hardship to any one. It will either have to be done very shortly or in spite of all our efforts at restoration the fisheries will fail.

As I have pointed out in a previous paragraph the creation of small areas by reservation as natural spawning grounds for the nest-building fishes will accomplish the end aimed at in maintaining those fishes. This can be done at practically no cost to any one either in time, money or in legitimate fishing, but to accomplish these things and perpetuate fishing we must have the active support of every person engaged in this recreative sport.

At this time the thought most foremost in our minds is the maintenance of our streams and lakes. To accomplish this we must keep pace with the increasing demands by an ever increasing output. During the fiscal year ending June 30, 1929 we planted in state waters 595,843,000 wall-eyed pike and 86,660,000 whitefish fry, an enormous increase over any previous season. If we suffer but the normal losses from now to the completion of stocking operations we shall distribute during the calendar year 1929 approximately 6,000,000 brook, brown and rainbow trout from 3 to 6 inches in length an increase over the calendar year 1928 of about 1,850,000.

XXVII.—Discussion

Mr. Thaddeus Surber: Minnesota stocks annually with pike over seven hundred lakes, and it is not a question of planting fry, it is a question of transportation. As an example of the prohibitive cost of providing our lakes with a reasonable number of pike fingerlings, I will take Mille Lacs Lake as an example. Mille Lacs Lake is one of our best pike lakes in the central part of the State. Actual statistics indicate that approximately three million wall-eyed pike are caught in this lake each season. We plant in that lake from three to six million fry annually. To replace the adult pike taken from that lake by the anglers would require at least three million pike fingerlings annually. The distribution of pike fry to that lake costs $40 per three million, whereas the same number of fingerlings, three inches long, would cost $7,985.

PRESIDENT CULLER: It is not that you are unable to raise them, but that it is not practicable.

MR. THADDEUS SURBER: Exactly.

PRESIDENT CULLER: That is the point I wanted to bring out, because in the minds of a great many there is doubt as to whether or not you can rear pike perch.

MR. THADDEUS SURBER: I sometimes doubt whether it can be done economically on a large scale, but our chief problem is transportation. We have long hauls from our hatchery, which is located in the southern part of the State. In order to distribute fish in the northern part of the State our fish car will cover a mileage of six hunded miles on the round trip.

MR. C. AVERY: It is manifestly impracticable to attempt the rearing of three to five hundred million wall-eyed pike beyond the fry stage. Those who are familiar with the pike perch operations know that a great deal of the fry that is planted is wasted. It seems to me that the important problem is to find out why results are not obtained in all cases from planting the fry; whether it is some fault in the planting, lack of food, or some other factor. The fact that Mr. Albert has shown that he can raise a limited number of wall-eyed pike to an advanced stage indicates that it might be worthy of trial in other states. It would be impossible, of course, to rear large numbers, but it might be possible to establish pike in lakes where we have not been able to establish them through planting fry and in that way extend the distribution of the most important fish now propagated in Minnesota.

I wonder if the members of the American Fisheries Society realize the significance of the figures which Mr. Surber has presented. I believe that Minnesota produces for planting more wall-eyed pike fry than all the other States and the Bureau of Fisheries combined. The propagation of wall-eyed pike in this State is expanding. The facilities for hatching have been increased and the work has been conducted so successfully that, while a number of years ago we were fearful that our wall-eyed pike might disappear in Minnesota, it would not seem from present indications that there is any immediate danger.

DR. J. VAN OOSTEN (Michigan): Has anything been done in Minnesota to establish a figure for the per cent of yield from planting fry?

MR. THADDEUS SURBER: We have no actual figures as to the success attending the introduction of fry. We introduced pike fry into a lake which had been entirely dry for two years; conditions became favorable, and the second season we had to permit the taking of under-sized pike because they were present in such enormous numbers that they did not grow. In addition to suckers which were introduced, the only natural food they had was insect larvæ. In a number of northern lakes which naturally had no pike, the planting of fry has produced excellent results. For instance, five years after we introduced the pike into Caribou Lake many pike that weighed six to eight pounds were taken. If pike fry are planted in deep water under our instructions there is no doubt of

success, but if they are dumped close to the shore they become the prey of the carnivorous fish which, hungry after their winter fast, when the waters begin to warm, congregated around the shore.

Mr. Patterson (Wisconsin): My thought was that if you had so many fishermen on one lake, how many would you have on all the lakes throughout the State and what should be the revenue to the State.

Mr. Thaddeus Surber: Mille Lacs Lake is more heavily fished than any other lake in the State. It is a big open lake, and the only thing that prevents fishing there daily is the prevalence of storms. There are two or three thousand boats on the lake. It would be hard to say what revenue we might derive from it.

Mr. Eben W. Cobb (Connecticut): Provided everything was legal, a man's catch could run into a good many hundred fish on his vacation at Mille Lacs Lake.

PROGRESS IN TROUT PROPAGATION IN MICHIGAN

F. A. Westerman

Department of Conservation, Lansing, Mich.

The propagation of trout, particularly brook trout has occupied a most important position in all of the fish cultural activities in the state of Michigan throughout the fifty-eight years during which artificial propagation has been carried on. Until three years ago practically the entire output of trout was planted at the stage when the food-sac was nearly absorbed. Only a few years ago it was believed that very material progress had been made when sufficient hatcheries were established throughout our trout zone so that 80% of our streams lay within a fifty mile radius, thus eliminating the long tedious and ofttimes wasteful hauls by rail.

Then followed the plan whereby hatchery crews in co-operation with Conservation Officers planted our trout. This of course necessitated providing trucks at all hatcheries. It also necessitated an inventory of our streams, particularly as to their location, size suitability for a certain kind of trout, etc. We soon realized how little we really knew about many of our streams, and lakes too. It naturally followed that a lake and stream survey of the state's inland waters was undertaken. This tremendous job will require years to complete, in fact it is a work that may be fairly said to be never done. However, we started with rather a high spot survey using available machinery such as local Conservation Officers, Fish Hatchery Overseers and interested sportsmen. This survey was followed in certain counties by a more careful investigation by our Land Economic Survey. This in turn will be followed by our biological staff as time permits.

We believe that this plan of planting by state crews has resulted in saving many thousands of trout. Such practices as applicants failing to plant fish promptly on arrival, dumping them off the first available bridge and planting streams totally unfit have been largely eliminated. More accurate planting records are now obtained since under the old plan of delivering cans of fish to an applicant at the railway station there was no assurance that the fish would be planted in the waters applied for.

The next important step in the interest of maintaining satisfactory trout fishing was the closing of the feeder or nursery trout streams to all fishing under the provisions of the so called discretionary power act. In this connection counties have been considered as units and sportsmen are invited to submit recommendations as to what streams shall be open to fishing. The closed streams are posted at highway crossings or at other conspicuous places. The streams open to fishing are named in our Digest of Fishing Regulations. This order has been in effect for four years. Annual revisions are made but no changes are considered dur-

ing the open season. This order is aimed particularly at keeping the unnamed and frequently unmapped feeder trout streams closed, also the extreme headwaters of the larger streams. We have not staggered open and closed sections; rather a stream is open from its mouth to some definable point upstream.

Two and one-half years ago we engaged in a further radical change in policy with regard to our propagation of trout, namely, feeding them for several months before planting. This necessitated a decided departure from our established hatchery routine. Many of you, who have long ago undertaken the rearing of trout in a wholesale way, know that it is one thing to hatch and develop trout fry to the feeding stage and quite another to carry them through to the age of six months. We are finding that some of our hatcheries are not well suited to this program and either must be devoted to some other use or abandoned. Our most urgent need is for increased trough capacity and for nurseries in which our trout may be carried from the middle of May until Septmber and October when they are planted. We are finding that under our conditions water supplies with a satisfactory winter temperature for incubation and early development are not always satisfactory for maximum growth throughout the summer months. For example we have spring water supplies with a stable temperature of 45° and 48° (F), respectively, throughout the year, which we prefer for early development. We find, however, that our trout grow much faster when transferred to streams where a higher summer temperature obtains. We are, therefore, establishing "Feeding stations" on some of our larger streams where we get summer temperatures of from 50° to 70° (F). These have been selected with the idea of requiring a minimum of effort to put them in shape for our use. They are located either below a dam or at an oxbow in a stream, by providing a cut off for carrying off surplus water. It is absolutely necessary to have the water supply under control, and to increase the amount flowing through the nursery as the fish increase in size. We believe they secure much more natural food in this way and the stronger current seems to add to their vigor. We aim to leave these nurseries in as nearly a natural condition as possible. We plan to locate them where we can carry at least, 250,000 fish. A caretaker is employed to look after screens, attend to the feeding and control predatory birds, animals and reptiles. These stations are necessarily more or less remotely located. The food is prepared at the hatchery and delivered in iced containers twice or three times per week.

We are carrying brook, brown and rainbow trout fingerlings in separate sections or ponds. In fact we find it advisable to provide separate water controls for the brook or speckled trout which are larger in size than the other species when these stations are in operation and require a stronger current than the smaller fish can well withstand.

These nurseries are in operation only about four months in the year. After the fish have been planted the screens and gates may be removed

allowing the stream to flow through. By the following spring the section has been well swept and scoured by nature.

We are operating 14 such stations at the present time and are carrying approximately 3,000,000 brook trout; 400,000 brown trout and 400,000 rainbow trout. Many of these fish are six inches long and they will average three to four inches when planted. The work is still in a stage of development, additional stations being established as suitable sites are found. We expect to ultimately have 25 or more stations under operation. In most instances we have secured long time leases from the owners. We have found owners very fair in permitting the state to acquire sites. Generally it involves the use of land of little value for any other purpose.

This plan for the rearing of trout was first used in Michigan by the Bureau of Fisheries in Cold Creek on the Turtle Lake Club grounds. How extensively it has been adopted elsewhere I do not know. I can, however, testify to the firm conviction that it holds large possibilities in maintaining satisfactory trout fishing under present day conditions. Reports on our trout fishing for the season just closed have been very optimistic. We hope to have more definite knowledge through the medium of the creel census and a check-up on the number of licenses issued. Also we are securing some interesting data on the migration of trout as a result of tagging operations.

XXVIII.—Discussion

MR. WESTERMAN: In connection with the creel census I will read a paragraph from the last biennial report of the Department of Conservation of the State of Michigan:

"Beginning July 1, 1927, a creel census has been undertaken in Michigan to provide information as to the average size of fish taken and the average time required to catch a fish, kind of bait used, etc. It is hoped in this way to get an index over a period of years as to how well game fish are being maintained, and whether there is an increase or a decrease. It is impossible of course to gather from this report what relation it bears to the total amount of fishing done, but some interesting comparisons may be made from the census for the year 1928. Outstanding is a rather surprising contradiction to the prevalent notion that brown trout and rainbow trout are replacing the brook trout.

A check of 2,707 reports shows:

12,556	brook trout taken	85.15%
1,799	rainbow trout taken	12.20%
390	brown trout taken	2.65%
14,745		100%

MR. G. C. LEACH (Washington, D. C.): A great change has taken place in Michigan during the last three years. Some three years ago they were producing about 40,000,000 brook trout fry and dumping them into the streams with doubtful results. I visited some of their hatcheries recently and found that they

are getting real results by rearing their fish to a large size, four or five inches, before they put them in the streams. The Bureau of Fisheries is also carrying on similar work in some 250 co-operative hatcheries scattered throughout the United States. A new method of feeding is being tried by feeding once a day at the remote places in the usual way by scattering food in the stream, and then suspending a pie plate about ten or twelve inches in diameter from a pole ten or twelve feet long, so that it is submerged four or six inches. In a pond possibly one hundred feet long we use four or five of these plates. After the fish are fed in the usual way we fill the pie plates and leave the food for the fish to consume at leisure. We have found that our death rate through cannibalism has been very greatly reduced.

MR. FARLEY (California): Might I ask what you are using for food in these rearing ponds?

MR. WESTERMAN: We are using almost entirely sheep liver, and in some instances pork liver where the sheep liver is not obtainable. The method of feeding is three or four times a day, as is the usual practice at the hatchery, and we aim to feed all the fish will consume. With regard to cannibalism, we find, of course, that some of our fish grow much faster than others. At times we are unable to get all the wild trout out of the pond. We examined fish through the summer months to determine whether or not any cannibalism was going on, and we have not as yet found any fish which were feeding on the other trout. Apparently the food that they were supplied with was sufficient to prevent cannibalism. I was also very much interested in Dr. Davis' paper yesterday in regard to the use of beef liver at the Bureau's stations. In Michigan we have quite generally resorted to sheep liver, largely because of the cheaper price.

MR. CRARY: When you say you give the fish all they will eat, do you allow the food to go to the bottom for ground feeding?

MR. WESTERMAN: We aim only to supply as much food as the fish will take as they are being fed. If there is any indication of some reaching the bottom untouched, we stop feeding. The feeding proceeds three or four times a day, so that they have ample opportunity, we think, to get about all that they can reasonably consume.

MR. CRARY: It is quite noticeable in feeding trout that they scamper off and will not take the food readily as it is thrown in. In order to give a proper amount of food it is a question whether you could feed from the surface. If they do clean it up on the ground, it is quite evident that it is not an objectionable way of feeding.

MR. WESTERMAN: I believe they will clean it up, as you say. It is better practice not to supply it in such quantities that it will settle to the bottom. We do not seem to have any trouble in holding the fish to the places where they are fed. The stations are divided by cross streams into sections two or three hundred feet long. The feeding is done throughout the entire length of the pond.

THE RESPIRATORY MOVEMENTS OF FISH AS AN INDICATOR OF A TOXIC ENVIRONMENT

DAVID L. BELDING

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The respiratory movements are an important aid in the diagnosis of fish disease and in differentiating the reaction of fish to a toxic environment. Our observations upon four species, the sucker *(Catostomus commersonii)*, the brook trout (*Salmo fontanalis*), the carp (*Cyprinus carpio)* and the goldfish *(Carassius auratus)*, indicate that respiratory symptoms as yet have not been fully utilized for the differential diagnosis of fish ailments.

NORMAL RESPIRATION

Respiratory System: On each side anterior to the gullet are four rib-like bones, the gill arches, each of which bears a double row of red fringes. The distal ends of the branchial filaments, which are united proximally, hang free. They represent the first four branchial arches; the fifth bears no gill. In certain species, on the inner surface of the gill cover, is a comb-like body with a single row of branchial filaments which represents the vestigial gill of the hyoid arch. By the rhythmical constriction of the heart the blood is forced into the ventral aorta, which carries it to the blood vessels of the gill filaments. After passing through the capillaries of the gill filaments, the oxygenated blood is returned for distribution throughout the body to the dorsal aorta, a large blood vessel with many branches which extends along the backbone.

Respiration: For the maintenance of life fish utilize the dissolved oxygen in the water. By means of the gills the blood, though separated by a delicate layer of epithelium, is brought into close contact with the water. Through this thin covering oxygen is absorbed by the blood, and carbon dioxid and other waste products are given off in a comparable manner to the respiratory exchange of air-breathing animals.

The gills are bathed with fresh water through the co-ordinated action of the mouth and gill covers. Water is taken in by opening the mouth, the gill covers separating slightly from the side of the head. The mouth is then closed, and the water is forced through the gills and finally ejected posteriorly between the gill cover and the side of the head, the action causing an outward extension of the gill cover. The latter movement appears almost synchronous, but actually is slightly later than the mouth action. On completion the gill cover returns to its closed position against the side of the head. The combined action of mouth and gill cover may be designated at the "respiratory movement."

Physiologic Changes: In the normal fish the respiratory movements are regular as to rate, volume, and force and only irregular when interrupted by a sudden movement or by an infrequent forceful gulp. The

respiratory rate is somewhat variable and the respiratory movements, which are automatically timed to furnish the proper amount of oxygen, fluctuate with the environment and the activity of the fish. Among the factors which may produce normal alteration in respiratory rate are: (1) temperature; (2) exercise: (3) new environment; (4) age and size; (5) diminished oxygen; and (6) species.

1. *Temperature:* The rate of respiration increases with the temperature of the water, owing to the diminution of dissolved oxygen and the increased metabolism of the fish, which has a body temperature slightly above that of the water. The respiratory rate in carp at a water temperature of 38 degrees F. ran from twenty-eight to forty-two, whereas at 57 degrees F. it ranged from fifty-six to seventy-six. Excessive or rapid increase in water temperature beyond the normal limits of certain species may produce pathological changes in respiration, but within the normal range there is a compensatory increase in rate for high temperatures.

2. *Exercise:* Activity on the part of the fish either natural or due to handling tends to increase the respiratory rate.

3. *New Environment:* A transfer to a new environment temporarily increases the respiratory rate, which is possibly the result of renewed activity and of handling. Carp, when placed in tubs of shallow water, immediately develop a different respiratory rate, but as they become accustomed to the change the rate gradually falls to the normal level where it is maintained for hours with practically no variation.

4. *Age and Size:* As a rule the respiratory rate of small fish is more rapid than that of large fish.

5. *Diminished Oxygen:* Up to a certain point diminution in supply of dissolved oxygen may be said to be within normal limits. As the minimum oxygen tolerance for each species is approached, the rate of respiration increases to compensate for the lack of oxygen. Further diminution produces pathological change.

6. *Species:* The respiratory rate varies with the species; e. g., the brook trout has a higher respiratory rate than the carp. Fish with a low respiratory rate are more sluggish and more resistant to environmental changes.

PATHOLOGIC RESPIRATION DUE TO DISEASE

Pathologic changes in respiratory activity may be produced by disease or by changes in the environment which tend to render existence impossible. The thin layer of epithelium covering the gill filaments is readily injured by parasites or injurious substances. The exposed position and the delicate organization of the gills render easy their infection by the numerous plant and animal parasites which infest the skin and external cavities of fish.

Respiratory movements may be altered by general disease and by

local pathologic changes in the gills. In systemic infectious diseases increased metabolism may change the respiratory rate, but unless the gills are directly affected no marked changes are apparent until the terminal stage is reached. With the approach of death the respiratory rate falls below normal and irregularities in rhythm and force are noticeable.

If the gills are injured by accident, parasites, local infection or chemicals, the respiratory rate is increased in order to compensate for the reduction in aerating surface. Primary or secondary bacterial or other plant infections which involve the surface of the gill and the presence of crustacean and worm parasites lower the efficiency of the gill in proportion to the extent of the injury. Acute inflammation resulting from active infection or severe irritation causes sudden changes but is probably less important than chronic inflammation which results in altered permeability of the epithelium. Abnormal developmental and structural changes occasionally produce pathologic respiration.

PATHOLOGIC RESPIRATION DUE TO ENVIRONMENT

The environment affects respiratory movements by a reduction in the dissolved oxygen and by the presence of toxic substances. Impurities of a technical nature, such as sand, clay, fine gravel, cellulose, fibers and other waste material have no appreciable effect, although fish may avoid such waters. Indirectly fish are affected by the destruction of their spawning and feeding grounds. The mere presence of large quantities of sediment does not interfere with respiration unless some active chemical stimulant produces an excessive secretion of mucus from the cells of the gill filaments. In this manner a chemical insufficient to affect fish directly may, in the presence of mechanical pollution, cause clogging of the gills and ultimately death of the fish.

Diminished Oxygen: Tests with reduced oxygen show an initial rise in the respiratory rate followed by a decline ending in the death of the fish. When the minimum oxygen level is passed, fish show symptoms of oxygen hunger. They come to the surface with increased respiratory rate and irregular forceful respiratory movements, which gradually become weaker and more irregular. Table 1 gives the combined results of several tests with diminished oxygen on carp, trout, and goldfish, confined in closed vessels with little oxygen. The initial rise is due to the new environment and to the stimulation of the respiratory rate by the lack of oxygen. The duration of the increased rate depends upon the species of fish, the amount of oxygen in the water, the temperature of the water and the relative size of the container to that of the fish. Of the three fish the brook trout is the most susceptible to lack of oxygen and the fall in its respiratory rate is rapid. Weak fish show little or no increase in rate and a more rapid decline.

TABLE 1.
Oxygen Reduction and Respiratory Rate.

Minutes After Fish Sealed in Jars	Respiratory Rate Brook Trout	Carp	Goldfish (Small)
0	80	65	60
1	110	65	120
5	135	100	110
10	100	70	100
15	90	60	90
20	40	50	90
25	20	45	100
30	0	40	105
60	----	20	100
90	----	0	110
150	----	----	100
180	----	----	65
210	----	----	25
240	----	----	0

Toxic Substances: Fish placed in water containing injurious substances show changes in respiratory action according to the nature and concentration of the toxic material. Injury of the delicate gill membranes manifests itself in the respiratory movements. Rapid alterations in the rate, force, and regularity of the respiratory movements may indicate the response of the fish to the absorption of toxic substances, which may be sufficiently characteristic to be diagnostic.

HYDROGEN SULFID

Hydrogen sulfid furnishes an excellent illustration of the effect of a toxic gas upon respiratory activity. This poisonous gas produces characteristic changes in the rate and quality of the respiratory movements. In one hundred parts per million in air death in dogs occurs in fifteen to twenty minutes after a violet hyperpnea followed by apnoea. With over three hundred parts the effect is fulminating and the respiration is suddenly paralyzed. Owing to the rapid oxidization to nontoxic compounds in the blood stream the poison is not cumulative.

Hydrogen sulfid gas is taken up by the blood through the gills in the same manner as it is absorbed from the lungs of animals. The blood is capable of oxidizing a limited amount of hydrogen sulfid, but any excess produces definite symptoms of death. For each species there is a minimum amount, probably in excess of the amount reported as present naturally in certain lakes, which the fish can stand without serious damage. A slight increase above the normal level of tolerance will produce a slow poisoning with slightly increased respiration, eventually leading to death. An excess will result in hypernea followed by apnoea and a marked excess will result in respiratory paralysis.

Since the dissolved oxygen in the water varies in proportion to the concentration of the hydrogen sulfid, the additional effect of diminished oxygen upon the respiratory rate must be considered. However, this factor is unimportant since the respiratory symptoms produced by hydro-

gen sulfid are distinct from those resulting from diminished oxygen.

Table 2 gives the results when suckers, trout, carp, and goldfish are subjected to various amount of hydrogen sulfid.

TABLE 2.

Action of Hydrogen Sulfid Upon the Respiratory Rate.

	Brook Trout	Sucker	Carp	Aquarium Goldfish	Wild Goldfish
Lethal dose p.p.m.	0.86	3.8	6.3	4.3	25.3
Test dose p.p.m.	2.6	11.29	12.6	42.3	25.3
Water temperature, Fahrenheit	60	60	68	48	68
Minutes After Exposure		Respiratory Rate			
0	80	50	66	50	60
1	0	49	0	0	16
2	----	36	----	0	----
3	30	----	----	----	0
4	----	----	40	30	----
5	----	----	----	27	----
6	----	0	----	----	----
7	----	----	----	----	----
8	----	70	----	----	----
9	10	----	----	----	----
10	3	85	----	6	15
15	0	60	44	----	----
20	Dead	48	----	0	10
25	----	----	48	----	----
30	----	----	----	----	16
60	----	40	24	Dead	6
75	----	----	0	----	20
90	----	30	----	----	----
105	----	16	----	----	----
110	----	8	----	----	----
120	----	0	----	----	----
135	----	Dead	Dead	----	28 Alive

The respiratory changes comprise an initial lowering or suspension of the respiratory movements, although occasionally in weak solutions only an increase can be observed. A partial recovery follows, the rate increasing, but rarely returning to normal. Gradually the respiratory rate declines until it ceases shortly before the death of the fish. The respiratory movements occur in groups at irregular intervals. The force varies, some being shallow, other deep and forceful. Also the duration and length of the respiratory movement may change. While all these symptoms, except the respiratory changes, may be found in fish subjected to other chemicals, the sum total of symptoms as given in Table 3 is sufficient to give a diagnostic picture of hydrogen sulfid poisoning.

TABLE 3.

Respiratory Symptoms of Carp from Hydrogen Sulfid.

Respiratory Symptoms	Hydrogen Sulfid—12 p.p.m.
Irritation	Marked
Loss of control	1 minute
Partial recovery	Present
Subsequent decline	Present
Rhythm	Irregular (early)
Force	Irregular and pronounced
Duration	Irregular (early)

The size, condition and species of the fish, the temperature of the water, and the strength of the hydrogen sulfid may at times cause surprising variations in the typical symptoms. The species, the relation of the size of the fish to the volume of water in the testing tank, and its condition at the time of the experiment influence its resistance. Of the four species studied the goldfish was the least and the trout the most readily affected. The colder the water, the lower is the rate of respiration and the greater is the resistance to hydrogen sulfid; e.g., carp at 40 degrees F. required 74 p.p.m. of hydrogen sulfid to produce the same toxic effect as 12 p.p.m. at 65 degrees F. High concentrations produce rapid death without the symptoms which are usually associated with weaker solutions. Table 4 shows the effect of different concentrations of hydrogen sulfid on carp.

TABLE 4.

The Effect of Different Concentrations of Hydrogen Sulfid on the Respiratory Rate of Carp.

		Hydrogen Sulfid p.p.m.			
Minutes	Control	3.2	6.3	12.7	25.3
0	78	78	98	66	88
1	78	40	30	0	4
2	78	56	30	4	0
5	78	64	30	40	0
10	72	64	48	44	12
25	74	64	48	48	24
50	78	60	16	24	12
75	76	78	12	0	4
125	66	60	Dead	Dead	Dead

SUMMARY

Respiratory movements in fish may serve as an indicator in determining certain toxic agents. Hydrogen sulfid produces a variation from the normal sufficiently characteristic to be diagnostic. Further observations of the respiratory movements may prove useful in differentiating other toxic agents.

XXIX.—Discussion

DR. J. METZELAAR (Michigan): The interesting and valuable contribution which Dr. Belding has made to the literature is of direct application to conditions in the field and in our trout hatcheries. In Michigan it is a well known

fact that there are some trout streams which differ from the standard type. In general we find that the trout are confined to the head waters, and that as you go down the stream is warmer and becomes gradually uninhabitable for trout. In some streams we have a condition which is just the reverse. The head waters will be rather slow moving, but further down the swiftness of the current increases, and although that water is considerably warmer, we find there the trout. I might mention as instances the south branch of the Pere Marquette in Mason County, the Presque Isle in Ontonagon County, and to some extent also the south branch of the Sunapee River, where the head waters are warm and classified as non-trout streams, but portions of the stream further down offer fair trout fishing. It has long been a question in the minds of some biologists if this was purely a matter of the swiftness of the current or if it was only indirectly the result. The opinion of Dr. Kreiser, who published a report not long ago on this subject, was that the occurrence of trout was exclusively or almost exclusively determined by the temperature. Obviously this conclusion does not apply to the instances I mention here. To my mind it is possible at least that in the slow moving head waters certain organic substances accumulate and produce such gases as hydrogen sulphide which, farther down stream, both by oxidation and by mixing of the water freely with the atmospheric air, become less in quantity. This might also be the case in some of our trout hatcheries, where the accumulation of feces and particles of uneaten food may produce noxious gases. I feel it is rather the territory of the chemist than the biologist, but it is an important and rich field for investigation which may lead to useful and surprising results.

MR. P. VIOSCA (Louisiana): The oxygen dissolved in water of course decreases as the temperature increases. In our warm waters, however, the plant life produces a supersaturated state of oxygen. The oxygen is undoubtedly present in a free state on the sides of filamentous algae, for instance, but it really exists in a supersaturated state in waters around ninety degrees, or even higher.

MR. EUGENE SURBER (Minnesota): May I ask if the fish exposed to hydrogen sulphide gas were transferred to water not containing this gas, would the abnormal respiratory rate continue for some time?

DR. BELDING: The time of the recovery is comparatively short, and would depend on the length of time they had been subjected to the hydrogen sulphide, and to its concentration. Usually the recovery is surprisingly rapid when placed in pure water.

MR. T. A. OLSON (Minnesota): Is there a method which may be used in the field for determination of hydrogen sulphide in the water?

DR. BELDING: The method could be carried out in the field. Of course it is difficult to record small amounts of hydrogen sulphide.

MR. TUCKER: What would be the parts per million of hydrogen sulphide that would be fatal to fish life at ninety degrees? We have a real hydrogen sulphide problem in our State. We are the chief sulphur producing State in the Union.

Dr. Belding: The highest temperature I have dealt with is seventy-five degrees Fahrenheit.

Dr. Emmeline Moore: Would the layman be able to read a diagnostic test easily enough to be sure that hydrogen sulphide is causing the respiratory reaction?

Dr. Belding: Unless the amount of hydrogen sulphide was near or below the normal tolerance of the fish, the early decrease or suspension of respiratory movement would be clear-cut and decisive.

THE RELATION BETWEEN ANGLER AND FISH CULTURIST

By Kenneth F. Lockwood,

Newark, N. J.

To one who has closely observed for many years the trend of affairs in public sport and conservation there is unlimited gratification in the growing relationship between angler and fish culturist, which is one of the more encouraging developments of the times. Above everything else, it makes for co-operation, which is just as essential to best results here as it is in any other form of human endeavor.

No long memory is required to recall the day when the only relation between the two was a rather detached interest on the part of each group in the work of the other, a state of affairs attributable to several factors.

In the first place, the mind of the culturist in those days was tightly wrapped up in the problems of production, and what eventually became of the fish after they left his hands was of no great concern. On the angler's part *his* thought was centered in pursuit of the fish and, if he was aware that somewhere behind the scenes a culturist was at work, he had practically no conception of the latter's problems and, therefore, no serious interest in them, or in him. The very term, fish culture, had only the vaguest meaning to the angler, that it had something to do with running a hatchery was about all he knew.

In the second place little or no information was available to the layman. The science was still in its infancy in this country and the culturist was feeling his way cautiously. Under such circumstances the scientific mind is quite likely to be uncommunicative, whatever the purpose to which it is devoting its energies.

A third contributing cause was the fact that when progress in artificial fish propagation by the states was under discussion the limelight of publicity almost invariably was turned on the high officials in the department, some of whom were not at all reluctant to stand in the limelight, and in addition were decidedly averse to sharing it with anybody outside their own little administrative circle. The culturist, an employe, remained in the background. The angler had no chance to know him, nor he to know the angler.

Little by little these deficiencies have been remedied, largely through the publicity of the press and the requests of wise commissioners that the public visit the state hatcheries. Consequently it is not at all unusual now to find an angler who has a fairly comprehensive idea of the problems of fish culture—at any rate the fundamentals. Naturally, this knowledge has created a real interest in the work, a realization of the value of the culturist to sport and, with it, a desire to co-operate whenever possible.

With all respect to department officials, most anglers realize that

the culturist who knows his job and his state is the real backbone of angling, and I am certain that the majority will agree with me that no policy of propagation and distribution should be adopted without his approval.

The culturist who is on the job does not shut himself up in his hatchery. On the contrary, he familiarizes himself with all waters that are stocked. He spends as much time as he can on the lakes and streams, obtaining first-hand information. He mingles with the sportsmen, in order to get their opinions. His ambition to produce a certain number of fish for the mere gratification of producing them and to earn his salary is subordinated to the determination that Tom, Dick and Harry shall have good fishing if it is possible for him to provide it. If fortune is with him he rejoices in their happiness; if ill luck besets him he isn't nearly so sorry for himself as he is for them.

Do not believe for an instant the angler does not appreciate that attitude—that he has not an equal personal interest in the culturist and his success. He has, the serious-minded, thinking angler, whose number happily, is increasing. There are few sport devotees who match him in the fervor of his enthusiasm, and in his regard for the man who is striving to provide the sport to which he is so attached.

On a fishing trip last spring I watched a stranger battle a fourteen-inch brown on a popular New Jersey stream. It was a thrilling fight and there were times when it seemed the fish would be the victor. Eventually, however, the angler won, killed his trout and creeled it.

"Man!" he exclaimed, "Charlie Hayford must have seasoned that trout's meals with red pepper!"

That man's comment certainly reflected an interest not alone in the fish, but in the culturist and in artificial propagation. No man who did not recognize the relation between angler and culturist would have had such a thought at the successful culmination of his battle with a good fish.

However there was more to the episode and further testimony to corroborate my point. I professed abysmal ignorance.

"Who is Charlie Hayford?" I asked.

He looked at me in surprise. He was so surprised he stuttered.

"Wh-why, man!" he exclaimed, "he's the superintendent of the state hatchery—the man that raises our fish. Say, you ought to take a day off and go up there and see how it's done."

It is my conviction, based on years of observation, that the relation between angler and culturist is strongest in those states which have adopted the policy of stocking with fish beyond the fry and fingerling stage. Naturally you can not expect the angler to have as much interest in fish dumped from the hatching troughs into the streams as in those reared until they are of sufficient size to insure a reasonable certainty of survival and can give an account of themselves on the end of a fishing line. In the one case interest in the fish and the culturist ends almost

before it has had a chance to get under way. In the other the entire time the fish are in the rearing ponds the angler feels he has a direct interest in them and in the man upon whom depends their welfare.

It is a rare individual who is unacquainted with the dangers confronting fish planted as fry or fingerling, owing to the veritable flood of publicity on the subject, in recent years. The angler has ceased to be impressed by official announcements stating that so many millions of trout (capital letters) fry or fingerling (lower case and parenthesis) have been put out, but he cheers loudly and long when he learns that so many hundreds of thousands of fish of legal length, or approaching it have been planted. The latter news stirs his imagination in addition to conveying to him an assurance that there will be fish in the streams when he sallies out. It does not seem to me at all a bad idea to keep the anglers in a state of pleasant anticipation.

There's another aspect of the subject that should not be overlooked, namely the financial end. When the larger fish are planted the angler feels that the money he contributes toward the support of the department, whether in license fee or tax, is soundly invested and will bring a definite return. In case of the smaller fish, he realizes that the whole thing is a gamble.

Of course, we all know that now and then a caustic critic makes a big hullabaloo about "liver-fed trout fresh from the hatchery." I would rather not at this time and in this place give my definition of such a person. For every one in my own state I can pick a thousand who commend the present system. If I wanted to step outside the state I would go straight to the White House at Washington, the occupant of which declared at Chicago, two years ago:

"One thing we do know and that is that it takes a host of fingerlings to provide for the survival of a fish of blessed memory. . . . It is the solemn fact that only some microscopic per cent of these fry or fingerlings, whether synthetic or natural, ever live to that state of grandeur which will serve as inspiration to polish the tackle or insure the approach to the battle in renewed hope with each incoming season. . . . We must either multiply the output of the hatcheries by some fearful number or find some other way out."

The other way to which he referred was the turning out of fish at a more advanced stage, through state and individual co-operation. As a Jerseyman, I am proud to recall he included New Jersey among the three progressive fish cultural states, saying that if every state in the Union would respond in the same manner the job would be done. I doubt very much whether you will find anywhere a stronger bond between angler and fish culturist than that which exists in New Jersey, the pioneer in stocking trout above the legal length.

The angler knows that it is the knowledge, ability and work of the fish culturist which has made this system successful. I say this, without the slightest intention to deprive those higher up officially of one

iota of the credit due them as the responsible heads of the department. The culturist who grows no gray hairs through worry or anxiety is as rare as the well known hen's teeth. He must indeed be a queer one if he finds no comfort in the fact that when troubles beset him thousands on thousands of anglers are back of him, hoping everything will come out right for his sake as well as their own. When things go well with him, the cockles of his heart are warmed by the knowledge that, largely through his efforts, fishermen are finding that unbounded pleasure which is the lure of angling.

A SURVEY OF THE FISHES OF CHAMPAIGN COUNTY, ILLINOIS[1]

DAVID H. THOMPSON

Illinois State Natural History Survey

It has been the aim of this study to find out some of the factors controlling the distribution and abundance of fishes in streams. Champaign county offers unusual advantages for such a study; not the least of which is the convenience of carrying on closely coordinated work, at once in the field and in the laboratory.

All the streams of this county are small and lend themselves to a more uniform method of treatment than is possible in larger streams; and they are unique in that they constitute the closely neighboring headwaters of six stream systems separated by water distances varying from one-hundred to more than twelve-hundred miles. The area occupied by these headwater streams offers an unusual degree of uniformity, since Champaign county is essentially a flat, fertile plain traversed by a system of glacial moraines which separate the different drainage basins. All the streams offer about the same variety of habitats in about the same proportions and show parallel variation in the physical conditions of the water. Extensive dredging of the streams has tended toward still greater uniformity, with only temporary alterations in the fish fauna. This uniformity tends to simplify the analysis and permits a number of biological factors and a few environmental factors to stand out boldly which in a more diversified area would be masked by a complicated maze of environmental effects.

Every effort was made to take samples of the fish fauna by methods as strictly quantitative as practicable, so distributed throughout the area and throughout the different seasons as to yield results which are at once clear cut and fully representative.

This study is based primarily on 28,905 fishes taken in 132 quantitative collections made in 1928. Forty earlier collections made from the same area in the course of a general survey of the fishes of the State in the period of 1881 to 1901 make it possible to detect any general changes during this interval, in distribution or abundance. These two series of collections, together with a few miscellaneous collections and reports from Champaign county, include representatives of 73 species.

On the basis of situations and conditions which occur repeatedly in these small streams, nine type habitats have been described, which correspond roughly with natural subdivisions in the distribution of the fishes. Different fishes vary widely in the number of these type habitats which they inhabit. Some kinds are limited to a single habitat while others occupy the entire list. However, those fishes found over a wide

[1]Abstract of a paper published in Volume 18 of the bulletin of the Illinois State Natural History Survey, 1929.

range of habitats invariably show abundances which vary greatly in different situations. In certain species presence or absence depends more directly on some detail of the environment than on the sum of more general differences between habitat types. Some kinds are found only among submerged aquatic vegetation, others, on certain kinds of bottom, in certain water depths, in certain stream velocities, etc.

These quantitative collections indicate that for the streams of Champaign county as a whole there are three fishes per square yard of water, or about 15,000 per acre, and that their weight is about 150 pounds per acre. Since both the streams and their fishes are too small to be attractive to many anglers, the catch in these waters is insignificant, so that this average of 150 pounds per acre of fish represents, primarily, the resultant of increase due to growth and decrease due to elimination by "natural" causes over an unknown period of years. We have no critical data showing what fraction of this 150 pounds per acre is annual increment or "turnover", but some fragmentary data and a general knowledge of the size and relative numbers of the different age groups, justify a guess that the annual turnover or growth increment in such headwater streams is an unexpectedly large amount of poundage.

The number of fishes per unit area varies from seven per square yard in extreme headwaters down to two per square yard in the larger streams, but this decrease in number of fishes downstream is more than counterbalanced by an increase in the average size of the individual fishes.

It has been found most convenient to compare stream sizes by measuring with a planimeter on a topographic map the area of the drainage basin at each point of collection. In comparing the range of stream sizes which different species inhabat, it was found most satisfactory to throw the data on drainage areas into size classes which increase as a geometrical progression, each class being made twice the preceding class. Number of fishes per unit area and number of species per collection, when plotted against stream sizes on this scale, give curves that approximate straight lines—a good empirical reason for assuming that this is a correct method of comparison.

Some species which reach their greatest abundance at a certain point on a stream also reach their greatest abundance in other streams at points where the drainage area is the same, without reference to distance from source or mouth. A tabulation of the number of each species in unit areas of streams of each size class shows that some are sharply limited to certain classes and that others are more generally distributed but fluctuate about a certain stream size as a mode. Although the young and adults of most species reach their greatest abundance in streams of the same size, the young of certain species of suckers regularly occur in smaller streams than do adults of the same species. Some of the factors which govern the distribution of the different fishes in the streams of different sizes are permanency of the flow of water, distribu-

tion of aquatic vegetation, sources of food, certain kinds of bottom, stream velocities, depths, and others which are dependent on the volume of water being discharged. The importance of the relation of the more important fishes to stream size is witnessed by the fact that quantities of typically large-river fishes planted in Champaign county streams in recent years have not appeared at all in our collections.

Extreme headwaters, on account of extreme fluctuations in physical conditions, constitute a most rigorous aquatic environment. Only a few kinds of fishes inhabit these waters, but these few kinds are abundant in numbers of individuals. They are generalized fishes, both morphologically and physiologically, apparently capable of meeting every emergency and reaching large numbers under exacting conditions in which other kinds cannot live. Their supply of animal food is haphazard at best, and all of them feed more or less habitually on vegetation, organic debris, or bottom ooze. While these fishes are most abundant in extreme headwater, they occupy almost every type of aquatic environment with varying abundances. They can tolerate pollution, and even in sizable streams, where pollution is moderate, they reach large numbers to the exclusion of other kinds.

In one stream draining an area of unusually fertile soil and superior crop yields, fishes occurred in numbers twice the average for the county as a whole. Furthermore, the average weight of these fishes was two to three times as great individually as the average for the county. There are also other evidences of their unusually rapid growth. Of the 34 species found in this stream, 15 were more abundant than the average for the county as a whole, and 20 kinds were more than twice as abundant. The silver-mouthed minnow, *Ericymba buccata;* the horned dace, *Semotilus atromaculatus;* and the Johnny darter, *Boleosoma nigrum,* showed greatest increases in numbers per unit area. The black sucker *Catostomus commersoni,* showed the greatest increase in weight, reaching poundages here ten times its average in the whole area. The piscivorous snapping turtle was found in this stream in numbers of 10 to 20 times the average for the county. The fertile elements of the soil leached into this stream seem to be utilized by the fishes in a rather direct and efficient manner. If large size and an unusually rapid growth are associated generally with unusually large numbers of fishes per unit area, this offers a means of roughly estimating the productiveness of waters by measuring the rate of growth of the more important kinds of fishes.

A few Champaign county streams are polluted by sewage from towns. The deleterious effects of sewage are most marked in the Salt Fork which receives the sewage of Champaign and Urbana. The evidence indicates that treatment of this sewage since 1915 by a modern sewage disposal plant consisting of Imhof tanks and sprinkling filters has not perceptibly increased the number or variety of fishes in the polluted part of the stream. Collections made in 1928 above and below the source of pollution in the West Branch of the Salt Fork indi-

cated 30 times as many fishes per unit area above as below and four times as many kinds. Collections made in the West and East Branches of the Salt Fork above their confluence showed six times as many kinds, and seventeen times as many fishes, with ninety-two times the total weight per unit area in the unpolluted as compared with the polluted stream. Further downstream in the Salt Fork the number of kinds, average size, and number per unit area all increase, but still are lower than for clean streams of the same size. The evidence indicates that in the Salt Fork, just as in other excessively polluted streams, the condition resultant from pollution which is most effective in restricting a normal fish population is a periodic lack of dissolved oxygen in the water. This deficiency of oxygen is caused by rapid oxidation of a heavy load of organic matter. Our findings indicate that most of the time there is sufficient oxygen for fish life in this stream, but that occasionally a sudden freshet stirs up the incompletely oxydized organic matter accumulated over many miles of stream length and produces a septic condition accompanied by the death of fishes or their retirement into cleaner water.

The fishes of Champaign county streams show three general types of morphological adaptation in respect to stream size and stream velocity. Those which inhabit the faster, shallower water and habitually cling to the bottom or hide behind objects which break the force of the current are typified by most darters, the hog sucker, and the stone cats. These fishes taper from the head to the tail, are roughly circular in cross-section, have large pectoral fins, and a high specific gravity. The local fishes which inhabit deeper and more sluggishly moving water habitually swim or float and are typified by the gizzard shad, certain minnows, and most sunfishes. These are laterally compressed and taper from the middle toward the head and the tail. They have a specific gravity almost the same as water and include those kinds which commonly leap into the air. In the third category we have a large number of fishes more generalized in body-shape and habits. They taper from the middle toward the head and tail and are roughly circular in cross-section. In this fusiform group fall the blunt-nosed minnow, horned dace, chub sucker, doughbelly, and other headwater fishes.

The stream systems of this area have no communication with each other through their branches, and their fishes can mingle only by traveling long distances and traversing widely different habitats, which constitute effective barriers to the movement of many kinds. Seventeen species which have been collected in sufficient numbers to avoid errors due to random sampling are absent from one to five of the six stream systems in which their preferred habitats are known to occur generally. All these fishes are small, have feeble swimming powers, and are either sedentary in habit or are restricted to special kinds of habitats. The absence of one of them from one or more drainage areas may mean that it never extended its range into these waters, or else that it has been

destroyed or driven out and has been slow in recovering. The evidence indicates that both explanations are necessary.

The horned dace is generally distributed in all parts of Illinois, but in the period of 1882-1901 twenty-five collections of fishes made in the streams of the Salt Fork basin failed to take a single specimen. In 1898, three individuals were taken in a hatchery pond at Urbana which may have seeded the whole basin, because at the present time it is the most abundant fish in the basin and was taken in 48 of 52 collections. In view of its wide distribution it seems less likely that the horned dace had never been in the Salt Fork than that it had at some time earlier been destroyed or driven out by some unfavorable condition or influence.

The distribution of the silver-mouthed minnow in Illinois in the latter part of the last century was confined to the Wabash Basin with some evidence that it was beginning to spread into the headwaters of streams flowing into the Mississippi, none being taken then in the Sangamon River in Champaign county although one was taken in the next county below. In the present study, they were taken in 26 out of 29 collections in the Sangamon, where this species is now more aboundant than any other of these species except one.

Such large changes in distribution and abundance resulting from "natural" causes suggest that artificial control of more important species may be feasible. In this connection a paragraph written in 1908 by Professor S. A. Forbes is particularly appropriate.[1]

"Attention may be profitably called, in conclusion, to the economic significance of the details of distribution of the various species, as influenced both by geographical and ecological conditions, since a proper understanding and application of these facts will prevent wasteful efforts to introduce species where they do not belong and can not thrive. Indeed, the more detailed our knowledge of favorable, and even optimum, conditions for the different species, and the more exact, also, our acquaintance with the relations of each species of fish to its companion species in any associate assemblage, the more intelligent and hence the more successful in the long run, will be our efforts to extend the range and multiply the numbers of the more useful species and to lessen the numbers of those especially injurious."

Seemingly conclusive proof has been produced that two abundant and widely distributed species of fishes show an association of such extreme exactness that the ordinary explanation of similar environmental preferences seems doubtfully applicable. These species are the shiner, *Notropis cornutus,* and the horny head, *Hybopsis kentuckiensis.* Although both of these fishes were absent from 77 of the 132 Champaign county collections, 99.7 per cent. of the specimens of *H. kentuckiensis* were taken in the presence of *N. cornutus,* and 98.9 per cent. of the *N. cornutus* in the presence of *H. kentuckiensis.* This similarity of distribu-

[1]**The Fishes of Illinois, by Stephen Alfred Forbes and Robert Earl Richardson, p. CVIII.**

tion cannot be due to chance isolation in the same drainage areas, because these are our largest and most active minnows and have been taken in every type of aquatic environment. This evidence of a close association of these species is borne out by their general distribution in Illinois and other areas.

It may be that some of the things which we have learned about the distribution and abundance of small fishes in small streams may be applied with profit to the larger and more important food and game fishes of larger streams.

XXXI.—Discussion

Dr. M. J. Johnson (Minnesota): I was particularly interested in the statement that the installation of modern waste and sewage disposal plants apparently has increased the abundance of fish life, and also in the statement that the limiting factor in the fish life of the stream was oxygen depletion due to the stirring up of sludge deposits. I would like to ask Dr. Thompson whether the sludge bottom deposits were left-overs from the period before the disposal plant was installed, or whether, even in spite of the treatment, further sludge deposits were being made on the bottom of the stream.

Dr. Thompson: No, the sludge was not a hangover. The stream is a steep grade and it is scoured thoroughly. The sludge comes from the filter beds in the disposal plant. It flows down and accumulates where the water is quiet. It gathers slowly, without complete purification; and then when it is stirred up it apparently takes up oxygen rapidly.

Dr. Emmeline Moore (New York): This remarkable paper is rich in suggestion, particularly with regard to the factor of fish associations. In stocking we should see that the fish placed in the waters are compatible. I think it was in 1921 that Dr. Forbes said at Fairport: "We have been studying the streams of Illinois for thirty years and we have accumulated a great mass of facts, but we have not yet related those facts to practice." It seems to me this paper presents one of the first achievements along that line.

A PRELIMINARY STUDY OF SOME TROUT WATERS OF ONTARIO

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Introduction

The various problems confronting fish culturists in different parts of the world are being investigated and the general principles evolved in any one region are in a large measure applicable in other parts. It is, however, a well recognized fact that each geographic division has many specific problems which, due to conditions prevailing in the region, can be solved only by an investigation of the water areas of that region.

The present study, being carried out by the fisheries laboratory of the Department of Biology, University of Toronto, consists of an investigation and comparison of various natural and artifical habitats of trout. It includes a study of natural and artifical ponds and lakes of different sizes, and of small and large streams in different parts of the province of Ontario. It includes also an examination of streams and parts of streams in which trout are not living but which are adjacent to waters containing trout.

Object of the Study

There are several phases of fish culture concerning which it is hoped some definite information may be obtained from this investigation.

From a study of the temperature, acidity, oxygen supply, available trout food, and rate of growth of the trout, the types of lakes and streams most productive of trout may be determined.

By a comparison of adjacent waters, some trout producing, others not, it is hoped that some knowledge of the factors limiting trout production may be obtained.

By a thorough study of the habitats and distribution of trout of all ages, the food taken at all stages of growth, the abundance and distribution of the food organisms, the life cycles of the various types and the apices of their abundance, information will be obtained of definite and direct value to those planting trout fry, fingerlings and adults in Ontario waters.

Finally the investigation should contribute data towards the solution of the outstanding problem confronting fish culturists, namely, the determination of the productivity in number and size of trout of any given stream or lake; the percentage of this number which will be produced by natural propagation under certain fishing conditions; and the number of adults that may be removed and the number of fish of a given size which must be planted annually to produce the greatest and at the same time most efficient yield for a stream or pond.

The Investigation

Geographical Divisions of the Province.

For the purpose of this study the province of Ontario may be divided on a geological basis into two major divisions; eastern Ontario, and southwestern Ontario in which the basic rock is of Ordovician, Silurian and Devonian origin, much of this, for example the Niagara limestone, being calcareous in nature; central and northern Ontario in which the basic rocks are the granites and gneisses of the old Precambrian continent.

The eastern part of the Province is roughly separated from the central and northern by a series of lakes and streams which are now joined to form the Rideau Canal System, and the southwestern part from the central and northern by a series of lakes and streams now joined to form the Trent Valley Canal System.

South and west of the Trent Valley Canal the water of most of the streams and lakes is highly alkaline, due to the presence of limestone. The water in the streams and basins of the Precambrian rocks, where muskeg conditions are often present, has a much lower alkalinity and in some cases is acid.

There are no trout in the eastern division nor in any waters forming the two canal systems. There are trout scattered generally over the southwestern part and the northern part of the Province.

The First Year's Work.

The first year's field work was carried out during 1928, by the junior author on ponds and streams in southwestern Ontario in four localities, Hornings Mills, Mulmur Lake, Glen Major and Caledon, widely separated but all in limestone country and all near the spring source of streams or small rivers.

At each location a careful analysis was made of the physical and chemical conditions of the water, and the algae and higher aquatic plants were examined. An intensive study of the invertebrate life was also carried out and in this special attention was given to the aquatic insects by Mr. F. P. Ide. The habits of the trout were observed closely and many specimens were taken and preserved for later study. The associated vertebrates which consisted for the most part of other fish, were studied with a view to ascertaining their relations to the trout as food, enemies, competitors or simply associates.

The Second Year's Work.

This study is being continued in northern Ontario waters where one outstanding difference is the lower ph. In general the ph of the streams and ponds studied during the first year was from 7.4-8.2 whereas the ph of the waters of the Archaean area have a much lower ph as indicated by Lake Nipissing, 6.8-7.4 and the waters of some streams and lakes in Algonquin Park, 6.0-7.6 (Table 1).

Biology of the Southwestern Ontario Ponds and Small Lakes.

The following account dealing with the study of the ponds and lakes only, gives in summary form the outstanding results from the investigation of the first year.

Little Wonder Pond

The most intensive work was carried out on Little Wonder Pond which is about two acres in extent which has a maximum depth of seven feet and into which two spring streams empty. In depths down to four feet this pond showed a production of invertebrates of 100-25 pounds dry weight per acre, in greater depths this production decreased to 25-5 pounds per acre.

The Trichoptera or caddis fly larvae of the family Limnophilidae were the most abundant of all the bottom forms. The larger trout were observed to eat the larvae in the cases, while the smaller trout first removed them from their shelter by seizing the larva by the thorax as it projected from the case and shaking it until the prolegs of the ninth abdominal segment lost their hold and the case was cast off. Of the Diptera, the Chironomidae or midges were abundant at all times, with the greatest emergence of imagos or adults taking place from June 10 to July 18. The midge pupae were taken in trout stomachs in greatest abundance about May 2. The Coleoptera or beetles were found to be abundant in shallow water, larvae of the genera Hydroporus and Haliplus appearing respectively about the middle of August and in September.

The molluscans were not uncommon and because of their almost uniform distribution throughout the year they form an important food item. One or two species of the genus Physa frequenting the shallow water and resting on Chara and Potamogeton, formed the most important food item of this group.

Hyalella knickerbockeri was the only amphipod found and its occurrence was infrequent.

There were two species of fish associated with the trout, a Cottus sp. sculpin or Miller's thumb, and Eucalia inconstans, the five-spined stickleback. The nest of sticklebacks containing eggs were taken on July 1, and in September many specimens of sticklebacks from ¾ to 2 inches in length were captured. Both of the fishes were eaten by the trout. The majority of the trout from this pond have a bright salmon coloured flesh.

Strother's Lake

Strother's Lake, situated near Little Wonder Pond, has an area of twelve acres, a maximum depth of twenty-four feet and has three spring streams emptying into it. The fauna is very similar to that of Little Wonder Pond with the exception that there is an abundance

of Hyalella knickerbockeri, and Gammarus limneus frequents the shores and shallow waters.

The flesh of trout from this lake is almost invariably a bright salmon colour. These trout yield eggs for Mr. Strother's hatchery. Spawning starts normally about October 15 and it is noted that about that time the fish feed less, the males feeding only occasionally and the females practically not all.

MULMER LAKE

Mulmer Lake is very different from either of the foregoing bodies of water. It is seven acres in extent, has a maximum depth of forty-two feet and is fed by springs on the bottom. There are no inflowing streams.

Trichoptera or caddis larvae of the genus, Limnophilus, were abundant; the adults emerging in large numbers from September 3 to September 6. Both damsel fly nymphs of the genera Enallagma and Lestes and dragon fly nymphs of the genera Aeshna and Gomphus were abundant.

Gammarus limnaeus was abundant in the Chara along the shores.

There were four species of fish associated with the trout, Rhinichthys cataractae, the long-nosed dace, Chrosomus erythrogaster, the red-bellied dace, and Cottus cognatus, the sculpin or Miller's thumb, being common. Cristivomer namaycush, the lake trout, was present in limited numbers reaching a maximum size of 12½ pounds.

During the autumn the speckled trout of this lake fed to a considerable extent upon terrestrial bugs, beetles and grasshoppers.

GLEN MAJOR

At Glen Major there is a series of four ponds with somewhat varying conditions, with a total area of four acres, a maximum depth of eleven feet, and two spring streams emptying into them.

The Trichoptera or caddis were common in the pupal stage during the middle of August. Of the Diptera, the Chironomedae or midge larvae were common almost everywhere. The Odonata or dragon flies were taken frequently. Of the Ephemeroptera, a species of Callibaetes was emerging in large numbers from August 5 to August 22.

The Cladoceran, Simocephalus, was abundant.

Hyalella was taken occasionally. Although Gammarus limnaeus was introduced on May 1928 none could be found in August of the same year.

Of the Mollusca, there were three genera of Gastropoda and three of Pelycopoda of which one species of Physa and one of Musculium occurred most frequently.

A Cottus sp? was the only fish, other than trout, found here.

CALEDON

There were two main ponds studied at Caledon. They had a combined area of two and one half acres and a maximum depth of ten feet, with one small stream emptying into them.

In these ponds there was a paucity of vegetation and apparently associated with this was a scarcity of invertebrate life. Chironomidae or midge larvae were almost the only forms found over the whole area but dragon-fly nymphs were quite plentiful in beds of typha. As a result of the scarcity of aquatic food organisms, the trout of these ponds fed to a very great extent upon terrestrial forms such as bees and adult stages of dragon-flies and stone flies.

Associated with the trout there were two species of fish, Cottus baridii, the sculpin, and Catostomus commersonii the common sucker. The latter fed upon the Chironomidae larvae, plankton and filamentous algae. As the Chironomidae larvae constitute 75% of the trout food the suckers come into direct competition with the trout. With a somewhat limited supply of food this competition is probably quite detrimental as it was found that many of the trout stomachs were empty. It is the custom to plant large or adult trout in these ponds in the spring to supply the fishing during the summer.

It will be seen that we have been dealing with five trout ponds which while within a limited geographical area, differ widely in their physico-chemical and biological conditions and in the productivity of trout.

Concurrently with the study of conditions in the ponds and lakes a detailed study of the food of the trout was carried out. It has been found that the food of the trout in the different waters varied in a marked degree, table II; that the food varied with the time of year, table III; and also that the food varied with the size of fish, table IV.

It is evident that there is a chain of factors in the production of trout in these waters. The size attained and the number of trout produced are dependent upon the character and abundance of the food supply and the latter in turn are directly dependent upon the nature of the body of water. For example, in cold alkaline lakes and ponds where Chara was abundant, trout were plentiful and of good size. The trout did not feed upon the Chara. They did however feed upon the organisms that made their home upon the Chara. This association of trout and Chara may be due to the fact that the Chara bore organisms that the trout utilized as food, or that the same physico-chemical conditions favoured the growth of trout, of Chara and of organisms that were the food of the trout. On the other hand, in waters where there was a noticeable lack of aquatic vegetation such as Chara, the trout did not grow so successfully, undoubtedly the result of lack of sufficient food as their alimentary tracts were for the most part empty or nearly so.

SUMMARY

1. The waters studied were situated in different parts of southwestern Ontario, where the basic rocks are sediments of Ordovician, Silurian and Devonian age, and due to the prevalence of limestone the waters have a high ph.

2. The ponds and lakes averaged about 4 acres in extent and all had extensive areas of shallow water about the shores at least.

3. Aquatic plants were found in most of the ponds and lakes and of these plants Chara was the most abundant and wide spread.

4. Aquatic invertebrates were usually frequent or abundant in the shallow water up to two feet in depth but decreased in numbers rather rapidly toward deeper areas. They were much more plentiful on a weed covered bottom than on bare mud bottom.

5. Of the invertebrates studied, caddis larvae of the family, Limnophilidae, and dipterous larvae of the family, Chironomidae, are worthy of special mention, the former being characteristic of the shallow areas the latter of the deeper water.

6. The trout depend upon the aquatic invertebrates for the great bulk of their food, utilizing other sources such as terrestrial insects that fall on the surface, and surface living forms, only when the supply of aquatic forms is not sufficient for their requirements.

7. The species of invertebrates differ in different waters. The aquatic insects in particular are not available as food in all of their stages, so the time of greatest abundance of available trout food varies in different waters. Some forms used as food such as the Mollusca were nearly constant in numbers and availability in many waters throughout the year.

8. Fine-spined sticklebacks and sculpins were the only other species of fish commonly found associated with the trout. They were occasionally eaten by the trout.

ACKNOWLEDGEMENTS

The financial obligation for this investigation during 1928 was borne by the Toronto Anglers Association of Toronto, Ontario.

The writers are greatly indebted to various clubs and individuals for allowing us to examine their trout waters and for their ready assistance in the study. These include The Caledon Mountain Trout Club and their manager Mr. Harry Overholt, The Glen Major Angling Company, The Mulmur Lake Fishing Club, Mr. L. C. A. Strother, Mr. John Mossop and Mr. Alexander Carlaw.

Many thanks are extended to Dr. E. M. Walker and Professor J. R. Dymond for advice and assistance in various phases of the investigation.

TABLE I

GIVING THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF BODIES OF WATER STUDIED IN 1928

Body of water	Area in acres	Greatest depth in feet	Summer Temperature: Surface range in degrees, centigrade	Summer Temperature: Bottom range in degrees, centigrade	ph.
Little Wonder Pond	2	7	14.9 —19.7	10.0 —14.4	8.2
Strother's Lake	12	24	15.0 —18.3	10.0 —16.1	7.6—8.0
Mulmur Lake	7	42	16.3 —24.0	12.8 —14.1	7.4—8.2
Glen Major Ponds	4	11	15.6 —21.4	9.0 —15.8	7.6—8.1
Caledon Club Ponds	2½	10	17.6 —23.0	12.6 —18.0	7.5—8.6
Lake Nipissing					6.8—7.4
Algonquin Park waters					6.0—7.6

TABLE II

GIVING THE ANALYSIS OF STOMACH CONTENTS BY PERCENTAGE OF 306 SPECKLED TROUT TAKEN FROM DIFFERENT WATERS IN ONTARIO DURING 1928

	Little Wonder Pond	Glen Major Ponds	Caledon Club Ponds	Strother's Lake	Mulmur Lake	Total
Number of fish stomachs examined	131	98	35	26	16	306
Caddis larvae and cases	28	30	3	25	50	136
Molluscs	23	11		15		49
Midge larvae and pupae	16	9	37	1		63
Fish	11	2		25		38
Aquatic beetles	5	15		1		21
Bees, Ants, etc.	1	3	37	1		42
Dragonfly and Damselfly nymphs and adults	1	8	10		20	39
Water boatmen	7		3			10
Vegetable matter	3	8		1		12
Fresh water shrimps	1	2	5	18		26
Leeches and Worms	1	4		6		11
Terrestrial beetles	3	1			10	14
Aquatic bugs		3		6		9
Mayfly nymphs and adults		3	3			6
Terrestrial flies		1	2	1		4
Terrestrial bugs					10	11
Grasshoppers, Crickets, etc.					10	11
Total surface food	4	5	40	2	30	81
Total submerged food	96	95	60	98	70	419
Total food examined	100	100	100	100	100	500

TABLE III

GIVING THE ANALYSIS OF THE STOMACH CONTENTS BY PERCENTAGE OF 131 SPECKLED TROUT TAKEN FROM LITTLE WONDER POND DURING 1928 TO SHOW THE DIET OF THE TROUT IN DIFFERENT MONTHS

	May	June	July	September
Number of fish stomachs examined	5	54	56	16
Vegetable matter	..	2	..	8
Snails	6	21	7	7
Caddis larvae	1	39	44	...
Caddis cases	1	16	29	..
Midges	86	8	8	5
Water beetles	..	1	6	18
Water boatmen	..	5	2	29
Terrestrial insects	..	1	..	32
Fish	6	2	..	..
Miscellaneous	0	5	4	1

TABLE IV

GIVING THE ANALYSIS OF THE STOMACH CONTENTS BY PERCENTAGE OF 131 SPECKLED TROUT TAKEN FROM LITTLE WONDER POND DURING 1928 TO SHOW THE FEEDING HABITS OF TROUT OF DIFFERENT SIZES

	5-7 inches	7-10 inches	10-12 inches	14 inches
Number of fish stomachs examined	56	59	14	2
Vegetable matter	2	1	..	..
Snails	12	14	51	4
Caddis larvae	34	42	16	4
Caddis cases	15	23	16	2
Midges	20	8	3	..
Water beetles	5	4	3	..
Water boatmen	5	4	5	..
Terrestrial insects	5	1	..	..
Fish	..	1	3	90
Miscellaneous	2	2	3	0

XXXII.—Discussion

DR. EMMELINE MOORE (New York): The correlation between the productivity of a pond and the geology of the region is most interesting, particularly in the association of chara in the limestone region and the direct effect upon the abundance of food organisms and the rate of growth.

DR. HARKNESS: I hope to have more data relative to a comparison of the limestone and igneous parts of the country ready for presentation.

DR. J. METZELAAR (Michigan): From how many trout were your data in these five ponds derived?

DR. HARKNESS: Little Wonder Pond, 131 trout; Glen Major Ponds, 98; Caledon Ponds, 35; Strother's Lake, 26; Mulmur Lake, 16, a total of 306 trout. All these fish except for an occasional trout were taken by sport fishing. We have followed a similar method to that employed by Dr. Metzelaar in Michigan, distributing hundreds of jars through the province for the collection of fish stomachs.

DR. METZELAAR: In presenting my paper yesterday, as time was limited I made no reference to seasonal distribution, which will be included in the paper when published.

DR. D. L. BELDING (Massachusetts): May I ask Dr. Harkness to explain the marked drop between the 12 cm. brook trout and the 14 cm. brook trout in regard to the type of food? From the tables there appears to be a difference of between two and ninety per cent.

DR. HARKNESS: As the trout grow, their gillrakers increase in size so that only the larger food organisms are retained. Since associated fish are the largest food organisms in a pond it is only natural that the trout should seek them instead of the small Dipteras and Caddis larvae. However, the small number of adult trout from which data were taken is inadequate for any definite statement.

DR. J. VAN OOSTEN (Michigan): Did you ever find fish eggs in the stomachs of suckers?

DR. HARKNESS: In all our work on the food of fishes in Ontario we have never found any fish eggs in suckers, although we have taken suckers from whitefish, pickerel, and herring spawning beds. But these observations do not mean that they do not take them.

DR. METZELAAR: I examined last year a large number of suckers taken from the bass beds in Grand Rapids county, Michigan, but I could not find any bass eggs in the intestinal tract. Nevertheless, I believe that suckers eat fish eggs at certain times of the year.

MR. THADDEUS SURBER (Minnesota): In Minnesota and North Carolina suckers are rarely present on the trout spawning grounds during the season

when the trout eggs are on beds. Consequently it is impossible to determine whether the suckers would subsist to any extent on trout eggs.

Dr. Harkness: In the larger rivers and lakes of northern Michigan and Ontario suckers and trout associate in large numbers in the spawning season.

Mr. J. A. Rodd (Canada): Occasionally a considerable number of brook trout eggs are found in the stomachs of suckers. When the suckers were present in the streams in which the trout were spawning the trout egg was the most abundant and the most easily obtainable food, and they naturally took what was most easily procurable.

WHAT SHALL WE FEED?

By Arthur S. Einarsen,
Biologist.
and
Loyd Royal
Assistant.
Washington State Division of Fisheries.

The problem of food for growing fish has been of paramount importance from the beginning of artificial propagation and to some extent has retarded the upward trend of progress along these lines. Fishes reared in captivity must be aclimated to an unnatural situation since it is impossible to simulate natural conditions in rearing ponds.

In the districts where salmon are found on the Pacific Coast of North America the matter of food for salmon fry presented a distinct handicap. Very little material could be drawn on with the exception of the salted carcasses of the parent fish. Altho raw liver was available at a low price, transportation and storage facilities were so inadequate or entirely lacking that liver could not be considered.

The salted salmon was used for years altho it never was considered a satisfactory food as it was impossible to obtain a food of uniform quality from it due to the difficulty of removing the salt from the flesh.

At time elapsed conditions again were changed and transportation and refrigeration facilities improved to a point where they could be considered.

The raw material for food, however, had risen in value to a point where some were entirely eliminated from consideration. Liver, is a very good example of this condition. During the early era of artificial propagation is could be had for the asking at slaughter houses or butcher shops. It gradually progressed to a value of 3c per lb. and for the past ten years has averaged about 15c per lb. in the Northwest and has been eliminated from our feeding program because of the cost. The cost of using liver at our hatcheries on an average day at present figures would run about $150 per day. Our present cost for raw material is nearer $30 making a saving that guarantees the continuance of an increased rearing program.

In a general way every one interested in the propagation of salmon has recognized the utilization of the parent fish as food for the progeny as being a logical solution of the feeding problem but as stated above the best cure or preserving method has never been entirely agreed upon.

Following the war, great quantities of canned salmon which had been improperly processed were made available to our organization; the State of Washington, Division of Fisheries. It was found to be usable,

it was cheap and could be both stored and transported readily. The condition of the canned fish, altho sterile, was far from being the most desirable food, but through experience in using it, we have developed a system of canning and feeding that marks the beginning of an era of mass rearing of salmon which is so vital to the perpetuation of the salmon industry. The spawned salmon are canned in No. 10 cans in connection with spawn-taking operations and stored for future use.

During the past winter in anticipation of an enlarged program of food preparation and rearing work we conducted a series of feeding experiments at the Green River Hatchery near Auburn to establish definitely the relative values of the various foods available and a few words in explanation of the project which will eventually be made available through a monograph, may be helpful at this time.

The foods considered consisted of (1) canned salmon of our own preparation canned without salt, (2) refrigerated fresh salmon eggs, (3) mild cured salmon eggs (cured with sugar and salt and refrigerated), (4) fresh raw fish, (5) herring meal,(6) salmon meal and refrigerated fresh eggs and (7) raw fish and refrigerated fresh eggs.

The procedure was to set up a group of troughs in each of which 250 Chinook salmon (Oncorhynchus tschawytcha) of a uniform age were placed. Along side of each experimental feeding trough was a control trough containing an identical group of 250 fish which were fed on the regular hatchery ration. Nothing was attempted in the way of quantitative feeding; that is, no definite unit of weight per fish per feeding was worked out; the obvious reason being that since small salmon feed only on particles in suspension and cannot feed from the bottom of the troughs, a quantitative system would be difficult to rely upon in conditions of varying circulation. It was the practice, however, to duplicate by whole weight the same amount in the control trough as was fed in the experimental trough adjacent to it at each feeding. In other words, the control trough and experimental trough received each a like amount of food at equal frequency.

The fish were weighed upon being placed in the troughs and thereafter once a week and the gain or loss noted. The weighing was done by the displacement method which, altho not entirely accurate to the grain of weight, very satisfactorily suited our purpose. These experiments were run from February 23, 1929 until May 17, 1929 which is a common length of time to retain salmon in rearing ponds as it is our policy to retain fingerlings only until they have reached a size to be better equipped for their own preservation and the ponds must be utilized successive periods yearly for new groups to be economical. The death rate per day in all the troughs was recorded and all deaths analyzed and causes ascertained as far as possible. The temperature of the water was also taken and close scrutiny of the experiments maintained at all times.

Since a work of this kind would fill a book, we can only give briefly the conclusions which may be drawn:

1. Salmon meal and fresh eggs give the best growth with the least deaths.
2. Salmon meal, made from our canned salmon, gives very uniform increases in weight per fish approximating the best feeds, but has higher death rate when the water temperatures are high.
3. Fresh eggs cause a continuous death rate which suggest a too highly concentrated food.
4. Mild cured eggs cause a low death rate but the fish make no appreciable gain.
5. Raw fish retards growth and increases death rate.
6. Herring meal retards growth and increases death rate.
7. Raw fish and fresh eggs decreases death rate but does not give normal growth.

In summing up the results of the experiment it may be said that the fututre of salmon rearing will be influenced by canning and refrigeration. It is possible to progress nicely with canned salmon alone and the economy of the process recommends it highly. Refrigeration alone does not seem to fill the needs. The canning of parent fish shows the greatest possibilities as there is little danger of increasing costs and as long as there are salmon to spawn we will have a ready supply of food.

This season three canneries have been installed at three centrally located hatcheries and it is our belief that our feeding problem is over and needs but the lapse of a few year's time to work out the refinements of perfection.

Q. What is salmon meal?

A. Salmon meal is a moist meal made from the spawned out carcasses of salmon which has been canned by regular canning methods at the hatcheries when spawn-taking is in progress. As salmon die after spawning, the utilization of their bodies for food is an economic saving since the general practice is merely to discard them into the river. The meal is prepared by pressing out excess moisture and working the canned salmon through a screen of eight meshes to the inch so that the particles which are pressed through are of a size small enough for two- or three-inch salmon to readily assimilate. The purpose of removing some of the moisture is to increase its buoyancy as any ideal food must remain in suspension in the water when fed since young salmon will not feed from the bottom of the pools. We have at present three canneries whose combined output is about 4,000 cases yearly of spawned salmon. Part of our cannery equipment is portable and after it is used at one hatchery it is then transferred to another station where the "run" of salmon is later in the year. In this way we avoid the expense of duplicating our equipment.

Q. What are No. 10 cans?

A. No. 10 cans are gallon cans running 6 to the case. The large cans are

more practical since the handling, filling, opening and storing is greatly reduced. Cans larger than No. 10's are not practical as with the solid pack heat will not penetrate them sufficiently to sterilize their contents.

Q. Where do you obtain fresh salmon eggs for feeding?

A. Fresh salmon eggs are obtained principally from canneries and fresh fish houses at very little cost to the department during the fishing season and are placed in 50 lb. boxes for storage until they are needed for feeding. These eggs have no other use as they are not mature and ordinarily go to the fertilizer plants to be made into fish meal.

Q. How long do mild cured salmon eggs keep?

A. Mild cured salmon eggs will spoil within 48 hours after being removed from cold storage where they are kept at a temperature of about 33 degrees. It is, therefore, necessary to remove them from storage just a few hours prior to feeding.

Q. In speaking of raw fish, what do you mean?

A. Raw fish mentioned in this paper means the freshly killed fish of spawned salmon during the ordinary hatchery operations.

Q. What is herring meal?

A. Herring meal is made of the whole bodies of herring ground and dried. Our source of supply comes from the herring fishery in Alaska.

Q. Does salmon meal keep well?

A. Salmon meal is only made in such quantities that will be consumed from day to day. One of the most dangerous practices in feeding fish is to use food of any kind that is inclined toward fermentation. For that reason our "meal" is made daily and used up or discarded before the next day.

APPENDIX

AMERICAN FISHERIES SOCIETY

Organized 1870

Certificate of Incorporation

We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certify in writing:

1. That the name of the Society is the American Fisheries Society.

2. That the term for which it is organized is nine hundred and ninety-nine years.

3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interests of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:

(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.

(b) To hold meetings.

(c) To publish and distribute documents.

(d) To conduct lectures.

(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.

(f) To acquire and maintain a library.

(g) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

Seymour Bower	(Seal)
Theodore Gill	(Seal)
William E. Meehan	(Seal)
Theodore S. Palmer	(Seal)
Bertrand H. Roberts	(Seal)
Hugh M. Smith	(Seal)
Richard Sylvester	(Seal)

Recorded April 16, 1911.

CONSTITUTION AND BY-LAWS

(As amended to date)

ARTICLE I

Name and Object

The name of this Society shall be American Fisheries Society. Its object shall be to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; the uniting and encouraging of all interests of fish culture and the fisheries, and the treatment of all questions regarding fish, of a scientific and economic character.

ARTICLE II

Membership

Active Members.—Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society.

The annual dues of active members shall be three ($3.00) dollars per year, payable in advance. In case of non-payment of dues for two consecutive years, notice shall be given by the Treasurer in writing, and such member remaining delinquent after one month from the date of such notice, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues, shall be ineligible for election as a new member for a period of two years, except upon payment of arrears.

Club Members.—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be five ($5.00) dollars per year.

Libraries.—Libraries shall be admitted to membership upon application and the payment of one year's dues. The annual dues for libraries shall be three ($3.00) dollars per year.

State Memberships.—Any State, Provincial or Federal Department of the United States, Canada or Mexico may, upon application and the payment of one year's dues become a State member of this Society. The annual dues for State memberships shall be ten ($10.00) dollars per year.

Life Memberships.—Any person may, upon a two-thirds vote of the members present at any regular annual meeting and the payment of fifty ($50.00) dollars become a life member of this Society and shall thereafter be exempt from payment of annual dues. The Secretary and Treasurer of the Society are hereby authorized to transfer members from the active list to the list of life members provided that no member shall be so transferred unless he shall make

request for such transfer and shall have paid dues as an active member of the Society for at least twenty-five years.

Patrons.—Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become a patron of this Society with all the privileges of a life member, and shall be listed in all the published membership lists of the Society.

Honorary and Corresponding Members.—Any person may be made an honorary or corresponding member upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President (by name) of the United States, the Governors (by name) of the several States and the Secretary of Commerce of the United States (by name) shall be honorary members of the Society.

Election of Members Between Annual Meetings.—The President, Secretary and Treasurer of the Society are hereby authorized during the time intervening between annual meetings, to receive and act upon all applications for individual and club mmberships. A majority of such committee shall decide upon the acceptance of such applications.

Voting.—Active members and life members only shall have the right to vote at regular or special meetings of the Society. Fifteen voting members shall constitute a quorum for the transaction of business.

ARTICLE III

Funds

Current Fund.—All moneys received from the payment of dues of active members, club members, libraries, life members, State members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

Permanent Fund.—The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

ARTICLE IV

Officers

The officers of this Society shall be a President and a Vice-President, who shall be ineligible for election to the same office until a year after the expiration of their term; a Secretary, a Treasurer, a Librarian, and an Executive Committee of seven, which, with the officers before named shall form a council and transact such business as may be necessary when the Society is not in session—four to constitute a quorum.

In addition to the officers above named there shall be elected annually five Vice-Presidents who shall be in charge of the following five divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.
4. Angling.
5. Protection and Legislation.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

Duties of Officers.—The President shall preside at the annual and all special meetings of the Society, shall be ex-officio chairman of the Council of the Society, and shall exercise general supervision over the affairs of the Society.

The Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, attend to the publication and distribution of its Transactions, attend to its correspondence, promote its membership, and arrange for annual and special meetings.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of one thousand ($1,000) dollars to be approved by the Executive Committee and to be paid for by the Society.

The Librarian shall have the custody of the library of the Society, including its permanent records and printed Transactions, and shall have charge of the sale of surplus copies of such Transactions. Other officers shall perform such duties as shall be assigned them by the President.

ARTICLE V

Meetings

The regular meeting of the Society shall be held once a year, the time and place being decided upon at the previous meeting, or, in default of such action, by the Executive Committee.

ARTICLE VI

Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Applications for memberships.
4. Reports of officers.
   a. President.
   b. Secretary.
   c. Treasurer.
   d. Vice-Presidents of Divisions.

   e. Standing Committees.

5. Committees appointed by the President.
   a. Committee of five on nomination of officers for ensuing year.
   b. Committee of three on time and place of next meeting.
   c. Auditing committee of three.
   d. Committee of three on program.
   e. Committee of three on publication.
   f. Committee of three on publicity.
6. Reading of papers and discussions of same.
   (*Note*—In the reading of papers preference shall be given to the members present.)
7. Miscellaneous business.
8. Adjournment.

ARTICLE VII

Changing the Constitution

The Constitution of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least fifteen members are present at said regular meeting.

AMERICAN FISHERIES SOCIETY
LIST OF MEMBERS, 1929-1930

(Showing Year of Election to Membership)

HONORARY MEMBERS

The President of the United States.
The Secretary of Commerce of the United States.
The Governors of the several States.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania.
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy.
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'93 Borodin, Nicolas, Museum of Comparative Zoology, Harvard University, Cambridge, Mass.
'12 Calderwood, W. L., Inspector of Salmon Fisheries for Scotland, Edinburgh, Scotland.
'04 Denbigh, Lord, London, England.
'04 Kishinouye, Dr. K., Imperial University, Tokyo, Japan.
'88 Lake St. Clair Shooting and Fishing Club, Detroit, Mich.
'17 Mercier, Honoré, Minister of Lands and Forests, Quebec, Canada.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'95 New York Association for the Protection of Fish and Game, New York City.
'08 Nordqvist, Dr. Oscar Fritjof, Superintendent of Fisheries, Lund, Sweden.
'06 Perrier, Prof. Edmond, Director, Museum of Natural History, Paris, France.
'92 Vinciguerra, Dr. Decio, Director, Royal Fish Culture Station, Rome, Italy.

CORRESPONDING MEMBERS

'84 Apostolides, Prof. Nicoly Chr., Athens, Greece.
'87 Armistead, J. J., Dumfries, Scotland.
'04 Ayson, L. F., Commissioner of Fisheries, Wellington, New Zealand.
'22 Director, All-Russian Agricultural Museum, Fontanka 10, Leningrad, Russia.
'22 Director of Fisheries (British Malay), Singapore, Straits Settlements.
'08 Higginson, Eduardo, Consul for Peru, New York City.
'84 Landmark, A., Inspector of Norwegian Fresh Water Fisheries, Christiana, Norway.
'22 Library, National Museum of Natural History, Paris, France.
'84 Marston, R. B., Editor of the Fishing Gazette, London, England.
'08 Potteau, Charnley, Lommel, Belgium.
'84 Sars, Prof. G. O., Christiana, Norway.
'10 Stead, David G., Fisheries Department, Sydney, New South Wales, Australia.

PATRONS

'14 Alaska Packers Association, San Francisco, Calif.
'15 Allen, Henry F., (Agent, Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour & Co., Battery and Union Sts., San Francisco, Calif.
'15 Armsby, J. K., Company, San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie & Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Wash.
'15 Bond and Goodwin, 485 California St., San Francisco, Calif.
'15 Burpee and Letson, Ltd., South Bellingham, Wash.
'15 California Barrel Co., 22d and Illinois Sts., San Francisco, Calif.
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore and Ballast Co., Inc., 210 California St., San Francisco, Calif.
'15 California Wire Cloth Company, San Francisco, Calif.
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